

Gravitation in Nature.

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THE
CORRELATION AND CONSERVATION
OF
GRAVITATION AND HEAT,
AND
*SOME OF THE EFFECTS OF THESE FORCES
ON THE SOLAR SYSTEM.*

BY ETHAN S. CHAPIN.

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AS A MARK OF
PARENTAL ESTEEM
FOR HER ATTAINMENTS,
I DEDICATE
THESE FEW PAGES TO
MY DAUGHTER,
MY COMPANION AND ASSISTANT
IN THOUGHT AND STUDY,
AMID THE
CARES AND PERPLEXITIES
OF A
DISTRACTING BUSINESS.

P R E F A C E .

THE igneous appearance of a large portion of the earth's crust, and its spheroidal figure, which would be incident to a plastic body of like dimensions and rotating velocity, have led some geologists to believe that the earth may have been, at some early day, in a molten condition. Some, on account of various phenomena, have conjectured that the central portions may now be in a fluid state.

But for alleged want of proof, the theory of a melted nucleus is very generally rejected. Dana says, "it is still an open question, whether the internal heat is that of fusion." It is true that the igneous appearance of the crust, and the spherical figure of the earth, do not prove its original fluidity. For the centrifugal force engendered by the axial rotation, and the denudating and transporting forces of the ocean in a northerly and southerly direction, consequent on the unequal temperatures of the water at the poles and equator, would long since have given the earth a spheroidal figure, had it been originally created a solid sphere.

Or had the earth in that ancient day of genesis been created without fire, this igneous appearance might have been imparted to the crust from volcanoes, if it were possible for them to exist, without a melted nucleus.

It was not from the appearance of the earth, but by the application of nature's laws, that I claim to have shown the convertibility of Gravity and Heat, and that the central portions of the earth

must be in a molten condition, among other subjects, treated in a pamphlet printed in 1864. While listening to a discussion on the physical condition of the moon, by the members of the American Academy of Science, held in Northampton in the Summer of 1865, I learned that they discarded the theory of a melted nucleus, laying great stress on Mr. Hopkins' discoveries. Mr. Hopkins might have been correct in his conclusions, had the precession of the equinoxes been correctly explained.

I have revised the article on Gravity and Heat, and annexed four unpublished sections, which were originally written several years before the publication of the pamphlet, in which I have considered the fallacy of the hypothesis of the precession of the equinoxes, as originally introduced by Sir Isaac Newton, on which Mr. Hopkins' calculations were based ; and also pointed out a few of the errors of adopted theories, which are more or less connected with the above subject. To establish the truth, it seems necessary to point out existing errors, while I appreciate most fully, the wonderful discoveries that have been made from time to time. If I take two cubes of the same matter equal in dimensions and temperature, one weighing a pound and the other a pound and a quarter, and reduce them from a moderately high temperature to an equally low one, I find that the denser cube will liquefy more ice than the rarer, or gives off more heat than the lighter, in reducing their temperature equally. If the process of heating the cubes is continued until they are fused, it would require more heat to fuse the denser cube. As the excess of heat in the denser cube is not indicated by the thermometer, I followed the former usage and designated it latent heat in the pamphlet, but according to the dynamic view, it is force. That is, as the denser cube contains more matter, it requires more heat to overcome the attraction of the cohesion of the particles and force them asunder. When the heat disappears it becomes force, the equivalent of the heat, heat and force being interchangeable, and like matter indestructible. It has been known for ages that heat was a force, that it expanded matter and produced motion. The

law of the correlation and conservation of heat and force is considered to be established, except in the case of gravity.

When using the word gravitation before one of the most able scientists in the country, I have been informed, that "it is not known that there is any gravitation, it may be the residuum of electricity, or it may be something else." Experiments indicate that electricity will not penetrate space void of matter, as the planetary regions are. One writer says, "force is matter in motion," and another that "the essence of heat is motion," and another that "matter is force."

It is evident that all matter in the universe has a tendency to move toward all other matter, whatever may be the proper form of expression. When Newton applied the word attraction, it seems that his views were sufficiently broad and comprehensive. He says in the Principia: "I here use the word attraction in general for any endeavor, of what kind soever, made by bodies to approach to each other; whether that endeavor arises from the action of the bodies themselves, as tending mutually to or agitating each other by spirits emitted; or whether it arises from the action of the æther or of the air, or of any medium whatsoever whether corporeal or incorporeal anyhow impelling bodies placed therein towards each other." When expressing the tendency of all matter in the universe to move towards all other matter, I shall use the familiar and comprehensive expression of attraction of gravitation. Its active force I shall consider a gravitating motion, and when this motion is resisted that heat is the equivalent.

In proof of the theories advanced, I shall apply some of the laws of nature, and make frequent references to the different articles, and introduce some very familiar illustrations. In attempting to apply the dynamic theory to the resistance of gravity, or in other portions of the discussion of these complex and intricate subjects, in popular form, I may fail to use the best form of expression.

Discoveries which have emanated from seats high in learning and influence have been very tardily recognized. Newton's biogra-

pher says of him, that although "he survived the publication of his great work more than forty years, yet at the time of his death he had not above twenty followers out of England." When Kepler introduced his immortal work he said, "It may well wait a century for a reader, as God has waited six thousand years for an interpreter of his works."

Therefore when I not only introduce new theories, but combat the errors of adopted ones, I may expect to wait long for an impartial reader.

Springfield, 1867.

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CONSERVATION OF GRAVITY IN A FLUID NUCLEUS.

SECTION I.

1. THE density of molten matter, congealed while subjected to pressure, is greater than if it were congealed free from pressure. As the force of gravitation decreases inversely as the square of the distance from the center of the earth, its condensing force is less powerful on the mountain heights than at the level of the sea, and less at the equator than near either of the poles. It becomes evident by all the tests that we can apply, that *the force of gravitation determines the density of matter.*

2. The expansive force of heat is antagonistic to the condensing effect of gravity, as is seen in the expansion of matter, when the temperature is increased. But the expansion of a fluid mass when its temperature is increased, is less, if the pressure is first increased. This is seen in many substances when the comparatively slight pressure of a portion of the atmosphere is removed from them, by plac-

ing them under an exhausted receiver. If we apply heat to water in this condition, we see how slight an incumbrance overcomes, in a measure, its expansive force, as in this condition, it expands so as to form steam, with less heat. *The expansive force of heat depends on the incumbrance of gravity, and the elasticity of the matter heated.*

3. In the Principia Book II., Prop. 20, Newton considers that a single particle is pressed towards the center of a spherical fluid mass, by the single force of its own gravity, and if the second particle rests on the former, that the pressure will be doubled. The third particle will make the pressure treble, the fourth particle will make it quadruple and so on.

Newton's law as here given respecting the pressure, like those given in our text books, to explain the expansion and contraction when the temperature is increased or diminished, is only applicable to matter in certain positions. If the outer surface of the first particle coincides with the general level of the earth, (which is represented by the surface of the ocean about 45° north or south of the equator,) when we place the second particle upon it, in this position, with its magnitude projecting above the general level, the pressure would be doubled, but as gravitation varies with the altitude, the pressure would not be trebled if we apply the third particle, and so on. The expansion and contraction consequent on a variation of temperature, contrary to the laws given in the tables of our text-books, also vary with the pressure. The exceptions to these

laws may not be perceptible in very limited magnitudes, but their effect on the magnitude of the earth becomes very perceptible. Without determining the amount of the variation in pressure, density, expansion or contraction, when the particle is encumbered by the weight of superior superficies at unequal altitudes, I will say that *the density of matter in all its forms depends on the force of gravitation and the weight of particle on particle*. The expansive force of heat must be considered in this connection. (See 2.)

4. If we fill a hollow tube a few feet in length with molten matter, when in a horizontal position, and then increase the pressure on the particle by placing it in a perpendicular posture, its contents are increased in density, and the same matter fails to fill the tube in its new position. If the matter contained in the tube was not heated, its density would not be sensibly affected by the change of position and slight increase of pressure. This experiment shows that *the expansive force of heat is more readily overcome when matter is heated*, and that the density of matter depends in a measure on the weight of particle on particle, for by placing the tube of molten matter in a perpendicular position, gravitation acts less on the matter, for it is removed farther from the center of the earth, but the pressure and density are greater.

5. When the density of matter is equal, the conducting power is uniform, but if we pulverize a solid body, or in any way increase or diminish the density of a body, (1) we increase or reduce its

conducting power. It is evident that *the conductivity of matter increases with the density.*

6. If we apply condensing force to a mass of liquid matter, it equalizes itself through the whole mass. If the liquid mass has perceptible depth, (4) particle rests on particle. The density of a mass in this condition is not uniform ; that of the inferior limb exceeds that of the superior.

7. If we apply heat to homogeneous matter having uniform density, (5) the conducting power tends to equalize the temperature in the mass ; if the density of the matter is unequal the denser portion receives the larger quantity, as the conductivity of the strata tends to convey heat towards the denser limb.

8. If we compress two cubes of air or matter into a smaller space than they previously occupied, they are henceforth less easily compressed. *The capacity of matter to sustain a crushing force increases with the density.* As heat, the equivalent of force, is made apparent by resistance, the temperature of matter is increased by compression, as all substances indicate.

9. Solid substances are more easily compressed when their temperature is elevated. (4) *The compressibility of congealed matter therefore increases with the temperature.*

10. Fused iron or granite under ordinary pressure, contracts one-eighth of an inch per foot in congealing. If the pressure is diminished at the time of congelation, (1) the density decreases but the amount of contraction is increased. If the

pressure is augmented, matter contracts less than one-eighth of an inch, the expansive force of heat having yielded to the pressure before congelation took place. *The amount of contraction in matter consequent on refrigeration depends in a measure on its density.*

11. This indicates that there is a point in the earth, where matter ceases to contract by pressure or expand by heat. Compression increases the density of matter, but as matter cannot be annihilated by pressure, the distance between the particles decreases, until the expansive force of heat is overcome, and the particles are forced into contact, by the overlying superincumbent mass, causing what may be termed a stratum of perfectly condensed matter, at a fixed point in the earth, and as heat is the equivalent of the intense force resisted, it must be intensely hot.

12. Many have experimented on the sustaining strength of the various rocks of which the crust of the earth is composed, but these experiments probably have not been sufficiently extended, on matter varying in density and temperature like the crust of the earth, to determine to what height a column of rock varying in density and temperature might be erected, before its base would become crushed. The height of the column would vary with the altitude, as the weight of matter increases as we proceed towards the poles, and decreases as we approach the equator, or ascend a mountain. If the shaft congealed at any of those several points, its length would be affected, for its density would

vary with the locality (1). If the shaft was cast in a perpendicular position in the earth, it would increase in density as we approach the base (3); the increase in density would add to its sustaining strength, (8) but as there is more or less heat in the surface stratum, the temperature must be increasing with the density as we descend (7), and the sustaining strength would decrease when the temperature became greatly elevated (9).

If the tables on the sustaining strength of rocks, are not sufficiently explicit to determine just how many miles in height a rock column, having these varying qualities, must be to crush its base, they are sufficiently so to determine the fact, that with the weight of comparatively few miles in height, the base of a column, composed of any representative rock found in the crust of the earth, would be crushed. The height of the column would vary, as does the force of gravitation, in different localities on the surface of the earth.

13. Further experiments may be necessary to determine or approximate the line in the earth, where we should find the crushing point, which is the fluid line, or the line where the fluid interior of the earth and the crust come in contact. As the density, conducting power, and temperature increase as we descend in the earth, and the sustaining strength decreases with the temperature, this line must be comparatively near the surface, as the sustaining strength of the perpendicular column having these qualities would indicate; and as has been shown matter is increasing in density accord-

ing to the pressure, but this increase is not maintained to any very great depth, as if so the earth would be vastly heavier than it now is.

The variation in the length or sustaining strength of the shaft, whatever it may be at different points on the earth, represents the thickness of the crust in these several localities. The diameter of the shaft may be unlimited, for adding to its base adds equally to the superincumbent weight.

The diameter of the crown of the column may represent the surface of the earth, and the diameter of the base, the point where the crust comes in contact with the melted nucleus; for when the base of a solid shaft is crushed, the resistance to the intense force (8) is perfect, and the crushed portion must be intensely hot, even to fluidity. If the shaft was cast in the earth in a perpendicular position, the crushed portions could not escape in a lateral direction, for matter in that direction would also be crushed, and it must be equally hot. (7) If we attempt to lengthen the shaft by adding matter to the crown, the base will crush. If we remove the superincumbent weight from the crown of the shaft, the heat will expand the crushed base of the column, and the intense fluid heat the equivalent of the crushing force will disappear, and the matter will be refrigerated. The length of the column will not therefore be increased or diminished, by lightening or overloading the crown of the shaft.

14. Heat, being the equivalent of the force resisted, not only tends to concentrate in the earth by compression, but also by conduction, for it

tends towards the denser limb (7), which if undisturbed always underlies a rarer stratum, thus concentrating the heat of the earth. Although heat is being constantly conveyed from the more central portion of the earth to the surface, by thermal springs, volcanoes and similar agencies, and beyond the surface by the expansive force of the atmosphere, it is not lost, (66) as it is conducted in an opposite direction, that is towards the center of the earth, by the increasing density, and therefore increasing conductivity of the strata in that direction. The prevailing direction of the currents indicates that they tend to produce an equalization of temperature; they therefore move in a general sense in opposition to conduction.

The tendency of heat to concentrate in the earth, may be seen when we place the tube of molten matter in a perpendicular position: (4) the matter contains the same heat, in its new position and decreased figure; it contains more heat per cube, and not only the increase in density (3) and in heat is greatest in the lower extremity of the tube, but the conducting power is also greatest in the same direction.

15. Again, that we may more fully realize the tendency of heat to concentrate in the earth, let us examine a stratum in a perpendicular column of sand. We find that there is a given amount of cohesive force per grain, and a perceptible increase in the number of grains per inch as we descend, as well as an increased resisting force; (8) we must therefore acknowledge that there is a correspond-

ing increase of force, the equivalent of heat. If we cast a shaft of iron in a perpendicular position, the conditions being such that all portions may be refrigerated as nearly as possible at the same instant, we find that there is an increase in density and in crushing force, as we descend the shaft, and an increased conducting power and consequent increase of heat in the same direction. If we continue to descend on this shaft through the crust, we find the same continual increase in crushing force, density, conducting power and heat, as far as we can penetrate, and as these properties increase in matter according to the pressure, we must calculate on the same increase in the impenetrable depths.

Could we penetrate these depths, we should find a line, where matter nearly ceases to contract by congelation, and the temperature is near the melting point, and by a further descent, we should arrive at a point where it ceases to contract by pressure, to a perfectly condensed and intensely hot fluid nucleus, uniform in density and temperature. (7) Matter outside of this line is lighter per cube, sustains less force, and retains less heat. Matter inside of this line is of uniform density and temperature.

16. The nucleus must be more dense than the crust, for a solid cannot rest on a fluid less dense than itself. It would sink as would ice on a lake that should be overloaded, and if a crushing force was placed on the crust equal to that on the melted nucleus, it would be crushed by the superincum-

bent weight, and made a fluid by the condensation.

(8) The crust rests on partially fused matter, and that on the melted nucleus, and heat is not conducted from the nucleus to the surface, as matter decreases in density and in conducting power in that direction. As the crust has been disturbed, the decrease in density is not regular ; but the conductivity of the strata decreases very regularly, owing to the intersection of comparatively rare matter, in veins, dikes, and fissures, at the time of the various disturbances.

17. The theory of a melted nucleus seems to be discarded by many scientists. The American Encyclopedia says, "It is controverted by Sir Charles Lyell, M. Poisson, and other eminent authorities, on these grounds. When substances, as metals, are melted, their temperature cannot be raised a single degree above the point of fusion, so long as a piece of the material remains unmelted. The same principle is exemplified in the impossibility of raising water to a higher temperature than 32 F., so long as a fragment of ice remains in it." These objections to a melted nucleus may at first seem unanswerable, but they vanish upon investigation. When a portion of matter on the surface of the earth is melted, it often is rarer than the remaining solid portion, and when brought into contact, the solid portion must be melted if there is sufficient heat, as heat is conducted more readily towards the denser limb. Metals that do not expand by melting or contract by refrigeration, have a uniform density whether melted or solid, and

owing to the equalizing tendency of heat, become equal in temperature when they are brought into contact. If the fused portion of any substance was denser than the remaining solid portion, the latter would take a superior position when they are brought into contact ; but the temperature of each will approach as near to that of the other, as does the density of inferior and superior strata of diminutive thickness. All must be said to be melted or all to be congealed, in a mass of matter of this magnitude, for it would be impossible to detect the variation of temperature in the opposite extremes of a stratum of such diminutive thickness, but a descent of from fifty to sixty feet, indicates a variation of a degree, if viewed independently of the varying surface influences. Water unlike the solids is a substance that expands when it congeals: the line of demarkation between the solid and fluid is very abrupt, although the variation of the thermometer may not be perceptible. The water is inferior, denser, and warmer than the particles of ice that rest upon it. If we place a second layer of ice upon the first, rarer than the former, it would contain less cohesive and resisting force the equivalent of heat, and this might be the case with many succeeding layers, and the temperature would be decreasing as we proceed up. The melted nucleus like the water, is denser and hotter than the crust that rests upon it, but as the variation of temperature,—unlike the case of the water and ice,—is considerable, between what may be termed solid and fluid, so the distance in the earth is considerable,

between perfect fluidity and the solid crust, comprising some miles of thickening matter, until we arrive at congealed matter, or a solid crust thirty miles more or less in thickness.

18. Mr. Hopkins experimented on different rock, and concluded that the density and conducting power of the inferior strata, far exceeded that of the superior, and on this account, inferred that the melted nucleus must be hundreds of miles from the surface. The temperature of the surface stratum is variable, but inside of that if the density and conducting power of the crust was uniform, the temperature must be equal. In this case, an inferior stratum of great depth, must have the same temperature as a stratum near the surface. But as the density of the stratum increases with the pressure (1), and the conducting power of a stratum increases with the density, the nucleus must be intensely hot.

The more rapidly the conducting power decreases, as we ascend from the melted nucleus, the nearer the surface should we find the fluid line. (17) Mr. Hopkins also made investigations to ascertain how far the observed amount of precession, might be consistent with the existence of a fluid nucleus, so that "in assuming the recognized period of precession, the shell in question must in order that it promote such a result, be at least one thousand miles thick." I shall reply to this fallacy in a succeeding section.

19. As the density of matter depends on the force of gravitation, matter must have existed prior

to its condensation by gravitation, and as the resistance increases with the density, (8) the matter of which the earth is composed must have been made hot by the condensation. *The time must therefore have existed, when the earth was in a molten condition.* Since the creation, gravitation has been producing its effects on the earth, and has by its powerful and all-pervading influence increased the density of matter, unequally in different portions of the earth, by the pressure of particle on particle, causing the central portions of the earth to be the more dense. Heat being more readily conducted by the denser matter, has receded from the surface to the denser strata, producing a thickening of the fluid, and in process of time solid matter, until we arrive at a depth at which matter ceases to contract by pressure and heat ceases to recede. The density and conducting power of the strata, are such that if the portion of the earth which is now the solid crust was in a fluid state at creation, the heat would have receded to its present limits.

20. In descending through the crust, which has been more or less disturbed, the increase in density and in heat would not be regular, and would vary in different localities, at the same depth. A large portion of the crust became hardened while subjected to greater pressure, than it is, in the position it now occupies, and dissimilar rock and strata vary more or less in their densities and power of communicating heat, when formed under equal pressure. These disturbances and variations cause the ther-

mometer to indicate different degrees of temperature, in different localities at the same depth.

21. Conduction has caused the fluid heat, that at creation was distributed through the matter that is now the solid crust, to recede to the denser stratum (7). The refrigeration and contraction of the surface stratum took place first, that being the least dense, and the inferior strata of the crust being refrigerated subsequently, caused a lateral pressure on the surface stratum, equal to the contraction of matter in the inferior strata by refrigeration, or the extra surface found in the general average of the heights and depressions on the surface of the earth.

22. If we calculate the crust to be thirty or even fifty miles in thickness, and to have contracted in congealing as much as iron or granite, in the same circumstances, which would be one-eighth of an inch per foot on the surface of the earth, and none at the other extremity, viz., the fluid line, the expansive force of heat at that depth having been overcome by pressure, (11) the medium contraction of the crust might then have been less than one-sixteenth of an inch per foot, as some substances are known to contract less than one-eighth of an inch per foot in congealing. Thus the earth would have been but a very few thousand feet larger in diameter, when in its fluid state than it now is. A crust thirty miles in depth may seem thin and unstable, but ice a foot in thickness will sustain many tons, and, a few rods in thickness, would sustain our largest structures.

23. As the refrigeration of the inferior strata ad-

vanced, a mechanical advantage was gained by the heavier portions of the solid crust over the lighter. This, together with the lateral pressure on the surface stratum, elevated the mountains and depressed the valleys. As the force of gravity on elevated matter decreases inversely as the square of its distance from the center of the earth, the continents and mountains as they were uplifted became self-sustaining. As their weight decreased by their elevation, the sustaining spherical form of the crust increased by the same, adding part of the weight of the mountains and continents to the valleys or more depressed portions, bringing an unequal pressure on many portions of the crust, causing currents and counter-currents on the surface, and great changes in the solid strata.

24. The changes which are now taking place are comparatively trifling, and more local, and are produced mostly by the aqueous agents, which are changing the position of matter and disturbing the equilibrium which exists in the crust. But the tendencies of nature to level the surface of the earth, by means of the aqueous agents and other forces, are counterbalanced. The removal of matter from one locality on the surface of the earth, allows as much matter to expand at the fluid line, as is caused to contract in another portion of the fluid line, by the addition of matter in some other locality on the surface. Any portion of the crust becoming overloaded is crushed by the force of gravity on the superincumbent mass, (13) and made a fluid by the resistance; while an equal amount of

the melted matter rises with those portions which are becoming lighter, above the line of uniform density. As there is less pressure, the melted matter expands, the fluid heat disappears with the intense force, and in process of time a uniform pressure, density, and temperature, is restored to every portion coming in contact with the fluid stratum.

25. The crust varies in thickness in different localities, as would the length of the column, (13) producing this uniformity of pressure. The unequal centrifugal force in different portions of the earth, does not effect the density, or the thickness of the crust only as it affects gravity. Centrifugal force poises the force of gravitation in a greater or less degree, according to the latitude. The thickness of the crust increases as we approach the equator, as the force of gravity decreases in that locality on account of the spheroidal figure of the earth. The crust at the sea-level indicates a medium thickness, and the more elevated portions show an increase in thickness equal to the elevation. As the diameter of the column very greatly exceeds its length, and its base is at the crushing point, it is liable to fracture through the shorter axis, and when the matter about the crown of the shaft undergoes a change of position, the localities on the earth where the crust is the most liable to fracture, can be designated.

If matter is being removed from any locality on the surface of the earth, as in the case of the crown of the shaft, the melted matter recedes from that locality. If matter is added to any district it ap-

proaches that district. The approach of the fluid nucleus to any point is equivalent to the subsidence of that point, and its recession from any point is equal to the upheaval of that point, when compared with the level of the sea, for while the melted nucleus conforms to the center of pressure, the sea maintains a level to that center. The altitude or the number of mountains when taken as a whole, is not being reduced by the leveling forces.

26. When large deposits of matter are being made in any locality, that locality is subsiding; while the district from which the matter is being removed is rising, bringing a longitudinal strain on the latter, and a lateral pressure on the former. The resistance of rock strata to a crushing force far exceeds its tension strength. Those portions of the crust which receive a longitudinal strain are liable to fracture, as some point near or at the summit of those which are being uplifted; and those portions which are receiving the greatest longitudinal strain, and are the most liable to fracture and allow the melted nucleus to be forced up to the surface, and at times to form volcanoes, are those lying nearly equidistant between the points of greatest upheaval and depression and are near the level of the sea. This is the line upon which faults are formed.

Some portion of the crust near that line and below it, is receiving matter and is subsiding; and some locality near that line and above it, is losing matter and is being uplifted.

27. When large deposits of foreign matter are being made near the coast, that portion of the con-

continent is subsiding. If the district from which matter is removed lies contiguous to any sea or ocean, that sea or ocean is retiring. Thus the sea is encroaching on the land, and the land on the sea, as alternately the solid crust is forming the bed of an ocean, the summit of a mountain, or is being condensed and made a fluid, whether it be igneous or aqueous strata. The melted nucleus expands and the fluid heat disappears from it as the force is removed, forming by this refrigeration the inferior stratum of plutonic rock.

This rock is being formed at points underlying the localities where the crust is being lightened, (13) and in the course of ages, is laid bare by the leveling forces on the summit of some lofty mountain, and in its turn furnishes material for aqueous strata, as compression brings the particles of matter nearer together (1), and under the power of cohesion, stratified rocks will continue to be formed by condensation consequent on overloading.

28. The older mountains are not always the higher, for the large deposits of foreign matter in a given direction from the base, causes them gradually to subside. The plutonic rock is therefore found in different localities, at all the intermediate levels between the ocean and the summit of the lofty and more recently formed mountains. From the position of the organic remains found in these stratified rocks, it is evident that they have at times formed the bed of the ocean, and the glacial furrows indicate that these stratified rocks, as well as the plutonic rocks, have been at times above the line of

perpetual frost, and ground down and defaced by the weight of glaciers.

It has been shown that the elevated and depressed portions of the earth are continually changing positions. Mountains with glaciers may have existed in every latitude on the surface of the earth. Rocks having a strong likeness to each other, that are found in different localities, and are said to belong to particular epochs, were formed by similar agencies at vastly different ages of the world, as is also the case with glacial furrows. Their similarity in appearance and structure is no indication that they have the same, or any definite age, although geologists have styled some former particular period the glacial and drift epoch, and named the rocks chronologically. The energy and extent of glacial action, or that of the drift, are not diminished as time advances, and they were never in the aggregate more active than at the present day.

Glaciers are grooving and transporting the moraines as in former days. Icebergs are smoothing, striating, and scattering boulders, gravel, and drift, on the floor of the ocean, as they did in past ages, when the present continents formed the bed of the ocean. As the motion of ocean currents, with their fields of floating ice which often touch the bed of the ocean, is from the poles towards the equator, the striæ they are producing, and the boulders and drift they are conveying, are strewed in a northerly and southerly direction, as we have abundant evidence over the surface of North America, as well as in other portions of the globe.

The uplifting of the crust from the level of the ocean to the line of perpetual frost, with the consequent changes in the currents of the ocean, gives to the same locality, in the course of years, a change of climate.

29. Since the earth, as a whole has ceased to contract, these changes have become less rapid ; but a few centuries makes them visible, in many localities on the surface of the earth. The subsidence may be seen near the points where large quantities of foreign matter are being deposited, as at the estuaries of some rivers, where trees are found buried in a growing posture below the level of the sea, as well as at other points where edifices have been immersed.

Promontories and even mountains are being submerged, and are forming islands in those portions of a continent which are subsiding, and other mountains composed of various strata, are being formed on those portions which are losing matter and are being uplifted. The uplifting of the land from the bed of the ocean, is the most apparent at points where extended high lands or mountain ranges are on the side of the continent bordering on the sea, as may be seen on the western coast of South America. In favorable circumstances, these changes of level are the most rapid, where the surface inequalities are the most visible, as is seen in the warmer climates (62). When many forces have combined to change the level of a particular locality more rapidly, implements of the aborigines have become buried to a considerable depth, causing un-

necessary doubt in the minds of some few eminent men, regarding the accuracy of the mosaic narration of the age of man on the earth.

30. The effects of this upheaval and depression are indelibly stamped in various ways on the solid crust, as is seen in the various fractures of cleavage, dislocation, &c. Fractures which were produced in the surface stratum at the summit of an uplift, or near the summit, are usually represented by a rent; those underlying the same locality in the inferior, hotter and more plastic strata, by a fold. Before the faults were disturbed, they were on a line near the level of the ocean. But if erosion and denudation were very unequal on opposite sides of the continent, they may represent a somewhat higher altitude. As volcanoes are formed on those lines where the changes of level are the most frequent, and where the crust receives the greatest longitudinal strain, they are found more or less in belts or bands (26).

31. It is not my purpose to describe the geographical or geological features of the earth, to note the variation or increase of heat as we descend through the crust, or to point out the localities where there have been the most frequent changes, or the most violent disturbances. These descriptions have been given, with more or less minuteness, by many writers on physical geography and earthquake phenomena. I propose to confine myself to the origin and cause of these conditions and disturbances, and indicate the portion of the crust, the conditions of the elements, and the seasons of

the year in which they are most likely to occur. As the currents of seas and oceans, with their denudating and transporting forces, are subjected to more frequent fluctuations than inland streams are, islands, peninsulas, and promontories, are more frequently upheaved and depressed, than is the case with the main-land ; as may be seen in the peninsula of Italy.

It has been suggested by writers on physical geography, that those inland tropical seas, which are receiving a constant influx of salt water through their straits, might be filling up with salt, from the almost constant evaporation from their surfaces. As previously shown (27), any extended portions of land, sea, or ocean, which are receiving large deposits of foreign matter, whether of salt, coral, or any other substance, are subsiding. There may be exceptions to this however. A point may be uplifted, when receiving slight deposits of foreign matter, if it is located nearly equidistant between two points, each of which is receiving an excess of matter, and is subsiding. The uplift would be produced by the solidity of the crust, before it is sufficiently overloaded to cause subsidence, as some coral islands in the central portion of the Pacific ocean may indicate.

Some particular localities are being uplifted when receiving deposits, if the district as a whole is losing an excess of matter, as is seen in some valleys, and in lake and volcanic regions. Lakes thus situated are gradually filling up, as is the case with Lake Geneva. Other localities are being depressed while

being lightened, if the surrounding district is receiving an excess of matter, as some islands, peninsulas, capes and promontories, indicate.

32. The subsidence of the heavier portions of the crust, and the rising of the lighter portions, is in accordance with the effect produced on an arch, the equilibrium of which is disturbed by lightening or overloading any portion of its span. The heavier portion subsides, causing the lighter to rise.

It is evident that the uplifted portions of the crust would be sustained in their elevated positions, as they lose a portion of their weight in being elevated, and as a part of their weight is added to the more depressed portions of the crust, in consequence of that elevation. That portions of the crust are being uplifted, and that a part of their weight rests on the valleys and more depressed portions (23), is manifest from the frequent land-slides. If it were not so, land-slides would be unknown, and perpendicular gravel and earth-banks would be a familiar feature in our landscape.

33. As the crust floats on the melted nucleus (16), and the inequalities on the surface poise each other, great mountain chains must be balanced by a deep sea, or a vast extent of low level plain. Astronomy teaches that the diameter of the earth is invariable ; the upheavals and depressions must therefore be equal. These motions counterbalance the effect of the leveling forces, and maintain an equilibrium in the inequalities on the surface of the earth.

The axis of the earth will not sensibly wander about or change its position, by the upheaval of

new mountains, at different points on the surface of the earth, as represented by Newton in the Principia Book I., Prop. 66, for the inequalities poise each other. New mountains cannot be uplifted without corresponding new depressions. If by any gradual denudating and overloading, the width of the Atlantic should become sensibly reduced, land would be upheaved in the Pacific ocean.

34. The leveling forces are not producing any very perceptible effect on the rocks which project above the line of perpetual frost, as is evident from their jagged appearance, but at a slightly inferior level they are working with great energy, as is seen in the heaving of the surface owing to the alternate freezing and thawing, and in the action of glaciers and torrents ; removing large quantities of matter, undermining precipices, forming overhanging cliffs, and at times frightful avalanches of earth and rock. These particles of rock and earth seek an inferior level, their weight is increased, and as they are transported to a greater or less distance, they are more or less deranging the geographical land-marks.

35. Although the crust has an arching and self-sustaining form, its sustaining strength is limited, by the same limited ability existing in the foot of the arch, and in the base of the perpendicular column (13). The solidity and sustaining strength of the crust, are such that it resists this gradually leveling process for a while, before yielding to a new position. This resistance causes the changes of level and the transition in the density of the matter to be more or less paroxysmal, rending the

solid crust, producing shocks or earthquakes by the fracture and concussion, at times forming new or reanimating old volcanoes.

36. The disturbance produced when the crust is fractured, varies with the nature of the soil, the face of the country, and the height at which the fractures occur. The motions imparted to the crust on the line upon which faults are formed, (26) are very complicated and violent, as a portion of the crust on that line is being uplifted and a portion depressed. When the crust becomes fractured, it frequently closes again. We experience, from time to time, these complicated motions and disturbances of the solid crust, in frightful earthquakes and similar catastrophes. When the egress of matter from the vents is unobstructed, the disturbing effect of the concussion on the surrounding crust is counteracted in a measure. Slight secondary forces are sometimes introduced, as the admission of fluids into the fractures of the crust, forming steam and gases.

37. Earthquakes more frequently occur when the disturbing forces are the most intense and act the most in unison, as when the earth is in that part of its orbit nearest the sun and moon, or when the sun and moon act in conjunction, and a high tide rests on the portion about to be depressed, or when there is a sudden decrease in the pressure of the atmosphere on the continent, or on a portion of the continent and ocean. While the pressure on the land would be greatly reduced, equal at times to the removal of two or three feet of water from the sur-

face, the waters of the surrounding ocean would flow in, on account of the greater pressure elsewhere, and keep up the weight on those portions being depressed (26). There are also atmospheric tides, corresponding with the tides of the ocean. When these tides are at their maximum at a given point on the ocean, other things being favorable, the ebb in the atmospheric tide, causes the barometer to be at its minimum on the adjoining continent.

As the sun passes the equator twice yearly, and the Spring tides are the highest when the sun is in that vicinity, earthquakes are most frequent when the sun is near the equinox.

As the land on the surface of the earth is more largely situated in the northern hemisphere, and has the least amount of ice, snow, and moisture resting upon it, when the sun has its most northern declination; and as the disturbances caused by the leveling forces have been accumulating during the year, and the vertex of the tidal-wave in a measure follows the course of the sun in its journey north and south, earthquakes frequently occur when the sun returns to the Summer solstice.

38. Irrespective of the conditions which control the expansive force of heat (2), a permanent increase or decrease in gravitation would cause a permanent increase or decrease in the density of matter (1). When the distance is diminished between the sun and any of the planets, the centripetal and centrifugal forces are increased. As these forces act in direct opposition to each other on mat-

ter, the tendency is, to increase or reduce the density of the bodies, according as these forces are increased or reduced. This may be demonstrated and fully proved by matter under our immediate control. The extreme eccentricity of the orbits of comets and their tenuity of substance, causes some of their disks to be sensibly reduced as they approach the sun, and may cause some of them to be self-luminous in that position. As the distances between the sun, moon, and earth are continually varying, and as the matter of the earth is alternately approaching, and receding from, the moon, by its motion on its axis, the density of the earth is very slightly affected by these varying influences. These disturbing forces cause continual motion of the melted matter in the volcanic vents.

39. As the artisan is not able to braze up the last aperture in the thin shell of a hollow metallic globe a few inches in diameter, on account of the continually varying pressure of the air resting on the inner and outer surfaces, so nature fails to refrigerate the melted matter in the vents, and close up the last apertures in the crust, on account of the constant transposition of the matter in the vents, caused by the ever-varying pressure against its inner and outer surfaces. For this reason volcanoes will always exist on the earth. If the fluid nucleus could be in a state of perfect rest, the uniform pressure of the solid crust resting upon its surface, would force it up through every vent and fissure, to a height nearly equal to that of the fluid nucleus before any refrigeration and contraction took place. This

phenomenon may be seen in many localities on the surface of the earth.* Owing to the continual motion of the melted matter, it may be carried still further upward by inertia, and form cones above that point. As the melted nucleus conforms to the center of pressure, and the sea maintains a level to that center, (25) the height to which the fluid would rise above the surface of the earth, should be calculated from the level of the sea, volcanoes being more likely to overflow at the sea-level, and less likely on the higher points, where the crust is thicker. The crust varies in thickness in different localities, owing to the variation in the density, in the force of gravity, and the unequal sustaining strength of the spherical form of the crust, in different districts and elevations. These inequalities and paroxysmal transitions in the density of matter, and the unequal egress of the fluid at the vents, giving different degrees of momentum, cause the melted matter to overflow, or stand in the vents, at different heights as regards the level of the sea.

40. As unlike matter in dissimilar inferior strata is being condensed and made a fluid (13) at different times, by the transposition of matter on the surface, various substances may be ejected from the same volcanoes or fissures at different times. While granite may be the basis of condensed matter, the various trap rocks may be the product of different fused strata.

If we would determine the weight of the earth,

*An illustration of this may be seen, at present, at the quarry of Hon. William N. Flynt, at Monson.

we should calculate the medium weight of the crust, and that of the fluid nucleus.

41. That the crust is thin, and the interior of the earth a fluid, is evident from the limited ability of refrigerated matter but a few miles below the surface, to resist the superincumbent mass of the crust, as is indicated in the base of the perpendicular column. If we take the intensity of the stratum of equitable temperature in connection with the centralizing tendency of the crust, (19) it shows that the interior must be intensely hot. Although heat tends to diffuse a uniform temperature in horizontal strata of uniform density, (7) when the density of any portion of the horizontal stratum becomes sufficiently reduced to admit of freezing, the power of conduction has become nearly or quite obliterated, so that it may remain for ages congealed, before being thawed by conduction, as many permanently frozen wells, and similar phenomena in various localities indicate.

42. That we may realize the transitions through which the heat and matter of the earth are capable of passing, let us take fifty parts of matter, and subject forty-nine parts, more or less, in a crucible to an intense fluid heat, and then add the remainder. It would all become a fluid. If the crust encircling the fluid nucleus could be broken up and pushed into the melted mass, the heat contained in the melted nucleus would restore the earth to its original fluid condition. In process of time, the heat would return to its present limits, and the earth would assume its present condition. If, after being

thus melted, the heat could not recede to its present position, it could not now maintain its present limits. If it was thus melted, the matter composing the crust would be expanded, the inequalities of the surface would be leveled, and the sphere enlarged, but the surface of the earth would not be very materially increased, when we consider the undulations and surface wrinkles of the present formation, for the crust originally congealed when the matter was thus expanded.

43. In establishing the law of the conservation of gravity and heat, it becomes necessary to show that heat disappears from, or increases by the cube in, two bodies, as they approach or recede from each other, in the same ratio as the force of gravity increases or decreases in those bodies. Gravity is a constant force, and heat its equivalent when resisted. When two bodies are attracted towards each other, the equivalent of the force of gravity is found in their accelerated motion. When that motion is resisted by any force, matter is condensed, and heat, the equivalent of the condensing force, is made visible.

44. If we should remove a particle of matter from any point on the surface of the earth, a portion of the fluid nucleus underlying that point would expand, and heat would disappear with the force. The solidity of the crust would resist a transition, under a particular point, causing the expansion at the interior to extend over a larger surface, but the melted nucleus would be diminished by the removal. If the matter thus removed was elevated to the

upper atmosphere, (as might be represented by attaching a body to a balloon,) the loss of heat in the portion of the fluid nucleus underlying the point from which the matter was removed, would be the same, (13) and heat would have vanished from that point, as gravity would by the square of the distance; and the elevated body would rest in an atmosphere less dense than that from which it was removed. As the conductivity of a homogeneous, uniformly dense stratum, diffuses a uniform temperature in a horizontal direction, (7) the temperature of the elevated body would be reduced to that of the medium in which it rests, and the frosts of a perpetual Winter might rest upon it. But if the body elevated has a fixed form, that has prevented it from expanding in an equal ratio with the loss of gravity, force, the equivalent of heat, has not been vanishing from it, as has gravity by the square of the distance. This can be made very apparent, if we imagine the body elevated a second time; this time beyond the influence of the earth. In this last removal, while gravity has vanished inversely as the square of the distance, the stored force in the body has not vanished, as the body has not been expanding. We therefore find that in elevating the body and thereby causing gravity to vanish, we have not removed the force of cohesion from the particles.

45. As matter must have existed prior to the condensing effect of gravity on the same, giving it form (19), gravity must have condensed matter before cohesion united the particles. As gravity

produced its effects first, it must vanish first. As cohesion originally fixed its firm grasp on the particles of solid matter by refrigeration, when the matter was under the condensing effect of gravity, heat must be restored to the solid matter, to cause cohesion to vanish, after the condensing effect of gravity shall have been removed. As gravity has vanished from the elevated body, if we should restore the previously refrigerated heat, and fuse the elevated body, cohesive force, the equivalent of heat, would vanish as has gravity, and the matter would expand in an equal ratio. The more rare the same substance, the greater is its capacity for force, the equivalent of heat, per pound.

46. As matter existed prior to its condensation by gravity, it might exist if gravitation should be removed. Gravity has been constantly producing its effects on the earth since the creative act, and as we are led to believe by Holy Writ* that the force of gravitation has been suspended or removed from a limited amount of matter, let us for a moment consider the effect, if it should be miraculously removed from the matter composing the earth. If it should be removed gradually,† the melted nucleus would expand, severing the crust into fragments, and as the fragmentary crust would maintain the greater density that pressure gave it, it would sink, and as heat is conducted towards the denser limb, it must be melted.

* Exodus, 14, 22; II. Kings, 6, 6; Matt. 14, 26—29; and similar passages.

† If it was removed rapidly, fragments of solid matter corresponding to meteoric matter, might be hurled into the surrounding space.

The prophecy in regard to the final consummation of all things would be literally fulfilled. The heat refrigerated from the crust, when under the condensing effect of gravity, would be restored. The elements would "melt with fervent heat and be dissolved," and the expansion would cause the earth to "pass away with a great noise." Gravity, heat, and cohesion would vanish, and matter would become rarefied in an equal ratio. While gravitation has power to condense the rarest nebular matter and produce heat, heat has power to expand the same matter to its original condition, if ever gravitation should be removed.

47. As the projectile forces have not been suspended, if we should restore gravitation to the particles of matter from which it had been removed, nature, with her present laws, would restore the present density, figure, and physical condition of the earth, but not its geographical positions. Matter would be condensed, and a melted mass would be produced. That portion of matter lying nearest the surface, not being perfectly condensed by gravity, would be refrigerated and form the crust.

48. As the ruins of some great conflagrations are not refrigerated in the course of months, and several years often elapse in the refrigeration of matter a few feet in thickness, ejected from a volcano at a single eruption; what ages must have elapsed in the refrigeration of the solid crust of the earth: epochs during which the temperature has been gradually decreasing on the surface. If the crust had not been disturbed, all portions would sustain

force and retain heat, equal to the density and conducting power of the stratum in which they were formed. As it is, all portions have retained heat equal to their primitive density and conductivity, and to those of the stratum in which they are found (20), and as the interior sustains an intense pressure, it is intensely hot, and in the economy of nature it must be so, in order to maintain motion in the fluids, and vitalize all nature. On account of the centralizing tendency of heat, if the nucleus was not intensely hot, the surface would be extremely cold.

49. The constant transposition of the fluids tends to equalization of heat, as is shown by the direction and temperature of the prevailing currents (14). The currents in the atmosphere tend to equalize its temperature, and its conductivity (7) and capacity to sustain force by the cubes, increase with its density (8), thereby increasing the refrigerating forces. Hence a dense atmosphere, on a still clear evening, facilitates the deposit of dew, or the appearance of frost.

50. In consequence of the centrifugal force and spheroidal figure of the earth, the tendency originally must have been to form the inequalities on the surface of the earth, nearly parallel with the equator (64). But the unequal temperature and equalizing tendencies of the air and water, in different portions of the earth, cause constant transposition of the fluids at the poles and equator, maintaining sea-communication in a transverse direction, from the vicinity of pole to pole, giving

form and outline to the continents, and determining mainly the direction of mountain chains. Currents moving in a northerly and southerly direction, as the Gulf stream, move more or less in curves, owing to the rotation of the earth on its axis, and always tend to flow in a line determined by a composition of these forces, wearing away in a measure all intervening barriers in the course of time. Complex currents often cause a deviation, as in the case of the union of the Gulf stream with that from Behring's Straits. On account of the centralizing tendency of heat, if the internal fires should become extinct, the pulsations of the globe would cease. The sun would continue to give motion to the atmosphere, but the earth would be transformed into a sterile waste.

51. The unequal temperature and density of water in the earth, causes springs. If we apply heat to the lower extremity of a column of water, the equalizing tendency is made visible by two currents, the warm current ascending, conveying the heat in an opposite direction from that in which it is conveyed by conduction, and the cold currents descending, showing that the internal heat produces motion and causes springs, and that artesian wells would overflow at, or above the surface of the earth, if it was a perfect sphere, as water stands the highest in the ascending limb. The variation in height of the water in two contiguous columns depends on their length, and on the unequal temperature, or weight per cube, of the water in the respective columns. Their temperature may be made such as

to cause a variation in their heights, of a foot in every twenty-three feet, or over four feet per hundred.

52. Water often descends into the ground warmer and less dense than it returns. By descending a few feet into the earth, we find ourselves below the influence of the impinging of the sunbeams on the surface, and arrive at a stratum of invariable temperature which absorbs this extra heat. As the water becomes more dense, it continues to descend, and takes the place of that below, which has been rarefied by the internal heat, and returns to the surface forming a spring. If its transit to the surface is very direct and quick, it may return hot, as we have examples in different localities.

If the temperature of the descending column, is reduced to that of the stratum of invariable temperature through which it passes, the temperature of the ascending column may be reduced nearly as low, and the water be returned to the surface, cooler and more dense than when it left. Thus while the water of a refreshing shower may enter the ground warm and insipid, it may be returned to the surface a cool and invigorating spring. The undulating surface and impervious structure of some of the inferior strata, are such that natural drainage, (which has been incorrectly considered the sole cause of springs, whether from natural or artificial apertures,) is an important agent in their production. These two forces may act separately or unitedly, in the production of springs.

As water free to move does not sensibly conduct

heat, and is but slightly compressible, its density may be increased by pressure, and still indicate a very high or very low temperature, if the pressure is such that it cannot expand to steam or ice.

As cold water is heavier than warm, and salt water heavier than fresh, when the distribution of water at the equator is equal to the evaporation, the colder and heavier waters of the polar regions may move towards the equator in an undercurrent, and when the evaporation is nearly constant, or greater than the distribution, the hotter, salter and heavier waters may sink to an equal depth, and move in an opposite direction.

GRAVITATION IN THE SOLAR SYSTEM.

SECTION II.

53. We have considered very briefly the law of density, and indicated a few of its effects on the earth. I shall consider that the same laws are applicable to the Solar System, as matter throughout the universe is equally attracted by gravitation, and obeys the same mechanical laws. Let us first consider some of its effects on the physical condition and peculiar motion of the moon.

54. In reading a paper before a meeting of the Academy of Science, noticed in the introduction, Prof. Alexander said, in substance, that the center of gravity in the moon does not coincide with the center of the figure, and that it is located farther from the earth, than the geometrical center of the moon. But he gave no reason for the statement. He may have based his assertion on the mathematical calculations of Prof. Hansen, the German astronomer. According to his theory, the moon's center is more than thirty-three English miles nearer us, than its center of gravity.

55. I have not seen his original calculations, but from the tenor of the following extract, I think that the fallacy of his hypothesis rests in his having compared the motion of the moon, to that of a ball hurled from a gun through the resisting medium of the atmosphere.

“In discharging a ball from a gun, calculation can predict the trajectory it will describe. But if the ball is not equally dense on opposite sides, it will not pursue the same path it would do if homogeneous. Given the difference of density the curve can be laid down, and given the curve, the difference of density can be determined.” The conditions are in no wise similar. The motion of the moon in celestial space is free from resistance, and depends on the centripetal and centrifugal forces, as will be shown in Section VI.

56. If we drop a guinea and a feather in a vacuum, they fall through equal spaces in equal times, but if let fall in the atmosphere, they do not reach the ground at the same instant. If the feather should be attached to the guinea, that portion of the guinea the farthest from the feather would arrive first, as would the heavier side of a ball, when the inequality of the density in the opposite sides is considerable. It is admitted that centrifugal force is excited in a revolving body, and that it increases with the velocity when the periodic times are equal. The periodic times of the superior and inferior limbs of the moon must be equal in their revolution around the earth. As the superior limb of the moon is the more distant from the earth, it moves in a longer

orbit. The velocity and centrifugal force of the superior limb therefore exceed that of the inferior limb. When centrifugal force is engendered in a mass of matter of unequal density, the rarer limb must move in the longer orbit where it receives the greater centrifugal force. That this is a law, and that it is applicable to the moon, can be demonstrated by matter and force at our command.

57. If we elongate a sphere of unequal density, so as to form an exaggerated representation of the figure and density of the moon, and poise it on the center of gravity through the shorter diameter, on a pivot that is moving in a circle, the longer and rarer limb will move in the longer orbit. I poise it on the center of gravity, for a force that moves the center is equivalent to moving the whole mass, and if all the particles are equally free to rotate, the axis invariably conforms to the center of gravity through the shorter diameter. If the inequality of density in the opposite limbs is extreme, the experiment must be tried in a vacuum. Again if the body is poised on the center of the figure, instead of the center of gravity, and if the pivot is caused to move with unequal velocity in an ellipse, representing the motion and path of the moon, the denser limb will not move in the longer orbit, but will be subject to more frequent axial rotation, caused by the unequal momentum existing in the opposite limbs.

According to the law laid down in Section I. the density of the inferior limb of the moon must exceed that of the superior limb, as gravitation acts

with more force on it; and the density of those portions having the greatest centrifugal force, is diminished by their being uplifted to a greater distance from the center of the mass (25). The rarer matter on the moon, as well as that on the earth, moves in the longer orbit where the centrifugal force is greatest. According to the law of density, the center of gravity in the moon must be nearer the earth than is the center of the figure, and according to the laws of motion, it could not move in an inverted position as suggested by Prof. Hansen, and again, if the trajectory of the moon depends on its unequal density, it does not depend on gravitation.

58. The distance between the sun and moon, being far greater than that between the earth and moon, the unequal attraction of the earth on the opposite limbs of the moon, greatly exceeds that of the sun on its opposite limbs. The preponderance of terrestrial gravitation on the denser limb of the moon, causes it to be a balanced figure, exposing only its loaded or denser limb to the earth.

The balanced condition of the moon explains the singular phenomenon, of the uniform rotation of the satellites of the different planets on their axes, with each revolution in their orbits, although the length of their orbits and times of revolution are unequal. Laplace said, "it is well known that the satellites present always the same face toward Jupiter, as the moon does toward the earth." Herschel, when speaking of the most distant satellite of Saturn, says, "it is presumed with much certainty

that this satellite revolves on its axis, in the exact time of rotation about the primary, as we know to be the case with the moon, and as there is considerable ground for believing to be so with all secondaries."

59. The moon is the more stable in its balanced position when it has its mean motion in its orbit, and its denser side is turned towards the earth and sun, as when the moon is in opposition to the sun. The unequal momentum in the superior and inferior limbs of the moon, caused by their unequal orbital motion, when taken in connection with the varying angular position of the sun and its unequal gravitating influence on the opposite limbs of the moon, causes the oscillations called the librations of the moon, in longitude and also in latitude, as the moon is balanced towards the center of the earth, and its path varies from the ecliptic. As the moon's orbit maintains an angular position from the ecliptic, and the heavier limb of the moon is turned towards the center of the earth, the polar axis of the moon is inclined to the ecliptic, thus determining the Lunar seasons.

60. By the application of the laws which have been cited in the first section, it becomes evident that the magnitude of the melted nucleus of the earth would be enlarged, the density and conductivity of the crust would be increased, its thickness would be reduced, and the surface temperature augmented, if gravitation should become more forcible, and *vice versa*. This law is applicable to all of the bodies in the solar system, and shows that

the density of the melted nucleus of all the planets is the same, and that their surface temperature does not depend on their distances from the sun.

61. It is said that gravity on the surface of the moon "is not more than one-sixth of terrestrial gravity." If we should transport the column (13) to the moon, its weight would be reduced nearly five-sixths, its length may therefore be increased in an equal ratio, before its base would crush. As the force of gravitation determines the density of matter, if the shaft was originally congealed in the moon, its density must be greatly reduced and its length increased, to produce sufficient weight to crush its base. The length of this last column would indicate the thickness, density, and conductivity of the crust, and the surface temperature of the moon. On account of the feeble force of gravity on the surface of the moon, owing to its diminutive size when compared with the earth, its crust must be very rare and thick, and its density and surface temperature much less than that of the earth; for the same reason, its atmosphere must be very attenuate. I did not determine fully, (3) what effect a variation of pressure would have on density, but gravity on the moon is said to be one-sixth of that on the earth, and its density (that of the earth being 1), is 0.5657, and the variation in the density of the heavenly bodies being all outside of the melted nucleus, the crust of the moon must be a few hundred miles in thickness. As the unequal refrigeration and contraction of the interior and exterior portion of the crust of the earth caused

the inequalities on its surface, (23) and as rarer matter contracts more in congealing (10), the contraction and formation of a rare and thick crust must cause great surface inequalities, as the disk of the moon indicates.

62. The crust of the earth is the lightest, as well as rarest and thickest at the equator. The greatest surface inequalities are therefore found in the warmer climates, as is seen in the altitude of table lands and mountain ranges. The crust being the rarest, lightest, and most elevated where it is the least affected by gravitation, more than one-half of the land, and the greater altitudes are located in the northern hemisphere. For the inclination of the earth on its axis and motion in its orbit, causes the south pole to approach nearer to the sun than the north pole, subjecting it to more powerful attraction, as the inequality in the influence of the sun on the opposite limbs of the earth increases, as the distance between them decreases. The variation in the force of gravitation in the two hemispheres is exceedingly slight, and the variation in the altitudes is also very trifling, when compared with the mass of the crust. As the line of the apsides of the earth makes an entire revolution in about 115,000 years, as calculated by some astronomers, and the uplifts and depressions on the surface are very gradually changing their position, the time will arrive when the excess of land in the northern hemisphere may be transported to the southern.

63. The decrease in the density of the planets, as the force of gravitation on them decreases, indi-

cates a homogeneous substance. Their density and physical condition are determined by the force of gravitation, but the ratio between their density and distances from the sun is not regular, as the force of gravitation varies with their mass, figure, the distance of the surface from the center owing to the unequal surface temperature (2), and the gravitating influence of each on the other, (as the influence of the moon on the earth,) as well as with their distances from the sun.

If we transport the column which represents the thickness of the crust of the earth to the planet Jupiter, its weight would be increased two and a half times, and if the column was originally congealed in that planet, its density and conductivity would be increased, the mass of the melted nucleus would be large, the crust dense and thin, and the surface temperature high. As the expansive force of heat is the most apparent when matter is the least encumbered by gravitation (2), the high surface temperature has converted the surface fluids into a vapory envelope, which encircles the body of the planet, making it very rare when taken as a whole.

Since first writing on this subject, I have learned that Laplace arrived at the same conclusion respecting the rarity of the matter near the surface of the planet Jupiter, when compared with the more central portions. "Taking for data, Jupiter's mass, diameter and rate of rotation, he calculated the degree of compression at the poles which his centrifugal force should produce, supposing his sub-

stance to be homogeneous ; and finding that the calculated amount of oblateness was greater than the actual amount, inferred that his substance must be denser towards the center." A high surface temperature greatly inflates the outer envelope, as Jupiter and the larger planets indicate. The same surface expansion may be perceptible in some of the comets as they approach the sun.

64. The loss of gravity must cause the surface of the exterior envelope of vapor to be very rare, with a correspondingly reduced temperature, as is the case with our upper atmosphere. The reflective power of vapor is greatly enhanced in a low temperature, and far exceeds that of land and water. That the outer envelopes of some of the larger planets are in this condition, is indicated by their great reflective powers, as well as by their variable surfaces.

The rapid motion of these planets on their axes causes their equatorial diameters largely to exceed their polar diameters. When fluids are very sensibly elevated by centrifugal force, as is the case in the larger planets, they will form more or less in ridges, at right angles with the axis of rotation. This is very easily demonstrated. Light reflected from deep ravines and elevated ridges would cause the surface to have the appearance of variegated belts, and ridges formed of vapor must undergo frequent changes by condensation. The physical disturbing forces on these planets must have great energy, caused in part by the rapid evaporation and condensation, which would give unceasing activity

to the leveling forces ; and also by their rapid rotation on their axes, and the mass and unequal revolutions of their moons. These, and the nearness of the fluid nucleus to their surfaces, would cause volcanic action on a very grand and extensive scale. The immense volumes of dark and heated vapor that ascend at times, would reduce the reflective power of the vapor hanging over a very large extent of surface. At other times, eruptions would cause a vast extent of surface to be covered with molten matter. The heat ascending from such extensive fields of melted lava would, in a measure, disperse, or illuminate the vapor suspended over an immense extent of surface. These convulsions may cause the more permanent spots on the disk of Jupiter ; those which do not disappear with a reconstruction of the belts. After spots make their first appearance, it has been noticed that their velocity increases, for awhile, with each successive rotation. As the ascending vapor leaves the body of the planet, its velocity is much less rapid than that of the outer envelope which it is penetrating, hence the proper motion of the spots is constantly increasing, until they acquire the velocity of the more rapidly revolving outer envelope.

As unlike density and temperature admit of different chemical combinations, the differing density and temperature of the planets may cause their various colors.

65. As the force of gravity on the surface of the sun is nearly twenty-eight times that of terrestrial gravitation, if the column (13) was transported to

the sun, its length would be reduced to one twenty-eighth of its length on the earth. If the shaft was formed on the sun, its density would be greatly increased, still reducing its length. If the length of the shaft in the earth, represented a crust twenty-eight miles in medium thickness, the column in the sun would represent a medium crust considerably less than a mile in thickness. The immense power of gravitation in the sun, causes the line of uniform density to be located so near the surface, that the refrigerating forces are insufficient for congelation, except now and then the formation of comparatively small spots or thin floating islands, in favorable positions. That the fluidity of the surface of the sun is dependent on the force of gravitation, is indicated by the spots on its surface being less frequent, when Jupiter and Saturn are at the perihelion, as was the case in 1800, and the most frequent when they are the farthest from the sun. In observations on the solar spots, W. Schwabe has shown, that the maximum and minimum of the period of spots, agrees very nearly with the periodic times of the larger planets. As gravitation is less powerful on the equatorial regions of the earth (25), it is also less powerful on the equator of the sun. The spots therefore form at times, and points, the least under the condensing effect of the force of solar and planetary gravitation, and they soon become liquefied by a relative change of position. The expansive force caused by their rapid liquefaction may carry the highly heated gas beyond a medium height, by inertia, and account for the lofty protuberances,

which have been seen projecting from the surface of the sun. The expansive force of heat, and the powerful condensing effect of gravitation on the surface of the sun, must cause the exterior envelope to be very dense highly heated gas ; as it were a very dense blaze. It has been determined by experiments on the polarization of light, that the surface of the sun is not incandescent, but is in a gaseous condition. As the spots or islands float on the melted nucleus, their naturally depressed condition accounts for the openings, where there is a visible island. That the gas overhanging the edge, or shore of these islands, is to some extent illuminated by the melted nucleus, producing the penumbra, is obvious by the disappearance of the penumbra at the point of contact, when any two or more contiguous islands intercept the light.

The faculæ may be caused by the accumulation of the floating specks in clusters, sweeping the surface owing to their mutual attraction, thereby increasing the brightness of the surrounding surface, just before the visible formation of an island. When the island first disappears, its perfect fluidity may also cause increased brightness. As intense density causes intense temperature, and this causes matter to appear radiant, the sun must be luminous, and as the temperature of a stratum depends on its density, the light of the sun must be as permanent as gravitation.

66. Those who have advocated the original fluidity of the earth, have considered that the surface heat has disappeared by radiation or otherwise

in space, by the cooling process, instead of being centralized by conduction. It is true that heat radiates from the surface of the earth, but we have no evidence that heat has passed beyond the bounds of the atmosphere. Nature saturates the atmosphere with a watery vapor, one of the most powerful absorbents of radiant heat, seemingly that none may escape. If any heat ascends beyond the more vapory portion of the atmosphere, it encounters a rare atmosphere of low temperature, which expands by the faintest application of heat, and the heat is converted into force, before it reaches the outermost limits of the atmosphere. When the surface of the earth was at a fluid temperature, the radiating force was vastly increased, but at that primitive period, all the water on the earth was held in suspense, forming a vapory envelope which would prevent any escape of heat. Neither can any be conveyed from the earth by conduction, for there is no perceptible matter in celestial space—as is shown in Section VI.

The vivifying effect of the sun is only developed into a quickening influence of heat and light, on its impinging the atmosphere or body of the planet. If the temperature of the earth depended on the heat actually radiated from the sun, its temperature must be increasing, as, in that case, the opaque surface of the earth could not radiate heat, as fast as it received heat from the glowing surface of the sun. Heat, being the equivalent of gravity, is as stable as gravitation. The resistance that condensed nebulous matter primitively offered to gravitation (8,)

caused the solar system originally to be in a molten condition, and if the force of gravitation should be removed, the matter of which the system is composed would return to its primeval condition.

THE THEORY OF THE TIDES.

SECTION III.

67. The Physical cause of the tides has been a controverted subject, during the various ages of the world. The ancients, very naturally, early attributed them in some way to the influence of the moon, as they maintained nearly the same angular position from that satellite. After the law of gravitation was finally established by Sir Isaac Newton, he assumed in the Principia, Book III., Prop. 36 and 37, that the gravitating influence of the sun and moon on the waters of the ocean, would elongate the fluid belt that encircles the earth sufficiently to produce the ebb and flow of the tides, but he calculated the density of the moon to be more than double its true density. Mathematicians of a later date have decided, that the "lifting power of the moon would not raise the water, or produce a tide of more than .07 of an inch, were the ocean 10,000 fathoms deep, and that the disturbing energy of the tangential force at its maximum, is only three-fourths of the maximum lifting force."

But in advancing theories of the tides, our text-books on Physical Geography and Astronomy, have diagrams and statements, showing that there would be a high tide formed under the disturbing body, if the earth did not rotate on its axis. Sir John W. Herschel says, "were the earth indeed absolutely fixed, held in its place by an external force, and the water left free to move, no doubt the effect of the disturbing power would be to produce a single accumulation, vertically under the disturbing body."

68. That the causes of the tides are not satisfactorily explained, (at least to some minds,) is frankly admitted by many that adopt the present popular explanations. Herschel says, "many persons find a strange difficulty in conceiving the manner in which they are produced. That the sun, or moon, should by its attraction heap up the waters of the ocean under it, seems to them very natural. That it should at the same time heap them up on the opposite sides, seems on the contrary *palpably absurd*."

69. In accounting for the tides by the hypotheses advanced in our text-books, there is not that analogy between cause and effect that should exist, when comparing the effect produced by the moon, with those produced by other forces of nature. "A variation of an inch in the mercurial column of a barometer, is equal to 13.4 inches in a column of water." A variation then of .07 of an inch in the mercurial column should cause the water to flow in by the greater pressure elsewhere (37), more than thirteen times as high as the direct influence of the moon would elevate it (67). As the mercurial col-

umn varies between two and three inches, it should elevate a tide in particular localities, nearly fifty times as high as the direct lifting force of the moon.

If the comparatively feeble tangential force of the moon, has any sensible effect in piling up the waters of the ocean, what vastly greater effects should we expect from the wind, when it sweeps over the surface of the ocean towards the coast, at the rate of one hundred miles the hour, with sufficient force to prostrate the sturdy oak and lay low extensive forests. The action of the wind, it is true, is confined more particularly to the surface, but the rapidity with which it forms and reverses currents in the ocean, indicates that it would drive in the waters of the ocean, much faster than they could possibly return by an under-current, on account of the immense amount of friction the returning inferior current must encounter on its entire surface. The lateral force of the wind should overcome the resistance, as effectually as the gravitating influence of the moon.

70. The variation in the pressure of the atmosphere over a specified locality, should cause at times, an elevation or depression of nearly three feet in the altitude of the waters of the ocean. The disturbing effect of these elements should therefore, if the adopted theories were correct, not only have their accredited effect on the oscillations of the ocean, but when they act in unison in favorable localities, they should supersede the effect of the sun and moon in causing the ebb and flow of the waters, and their results should be as much more marked,

as their forces are more visible than the influence of the sun and moon.

As the earth is very nearly a sphere, and the influence of the moon extends equally in all directions, if the tangential force of the moon sensibly elevated the waters of the ocean, a high tide would always encircle a point on the earth directly under the moon. If the direct lifting force of the moon sensibly elevated the water of the ocean, a high tide should culminate more directly under the disturbing body than is the case, as gravity is an active force, and matter free to move, has the greatest velocity at the point where it is the most powerfully attracted,—the velocity at once decreasing beyond that point as is seen when the earth passes the perihelion :—the more friction there is to retard the accumulating waters, the more it would favor this result.

71. But the theory which seems to many minds “palpably absurd,” is that given for the formation of a high tide on the side of the earth opposite the moon. It is said that the tides are principally caused by the unequal attraction of the moon, on the earth, and on the waters on its opposite sides, while the moon is only about one-eightieth the size of the earth, and attracts the waters on the earth nearly 3600 times less powerfully, than the same amount of matter in the earth attracts it, as it is nearly 240,000 miles distant. The moon, then, with its comparatively feeble force of gravitation, is said to raise the water of the ocean nearly under it, ten feet, more or less, and move the earth bodily five

feet, causing the water to hang back on the opposite side five feet, although the moon attracts the water on the opposite side of the earth, with nearly as much force as it does that on the side towards it, for only a small portion of its attractive force is lost in passing through the earth. According to this hypothesis, the attraction of the moon acting in conjunction with terrestrial gravitation, is not powerful enough to attract the water towards itself five feet on the opposite side, while the moon, acting in opposition to terrestrial gravitation, attracts it ten feet on the side towards itself. At a point on the earth near the nadir, where a high tide culminates, the water of the ocean is drawn by terrestrial gravitation towards the center of the earth, with a velocity sixty times as great, as that of the moon in its orbit towards the earth, which is nearly eighty times as great, as that of the earth towards the moon. What then is to prevent the water at the nadir from being attracted towards the earth by gravitation, as fast as the earth is falling towards the moon. In the adopted hypothesis of the tides at the nadir, it would seem that the force of terrestrial gravitation is ignored, while according to Newton's Principia, "the moon's force to move the sea, is to the force of gravity as 1 to 2871400. It is evident that this force is far less than to appear sensibly in statical or hydrostatical experiments, or even in those of pendulums. It is in the tides only that this force shows itself by any sensible effect;" and we must take into consideration the fact that he considered the density of the moon compared with the density

of the earth as 11 to 9, while modern tables give the density of the moon 0.5657, that of the earth being 1.

72. In proof that "the waters are raised, by the difference of the moon's attraction on the superficial waters on both sides, and on the central mass," Herschel says: "In the theory of the moon, the difference of the sun's attraction on the moon, and on the earth, gives rise to a *relative* tendency in the moon to recede from the earth, in conjunction and in opposition, and to approach it in quadratures." The planets are poised between the centripetal and centrifugal forces, and any slight disturbing force enters into a composition with these forces, and soon causes a sensible perturbation.

But if the earth and moon when free to move were "absolutely fixed," or destitute of orbital motion, and their mutual attraction as far exceeded the unequal attraction of the sun and moon as does terrestrial gravitation, which is holding the waters of the ocean in their position on opposite sides of the earth, gravitation would not cause them to recede from each other; on the contrary they would come in contact.

The unequal attraction of the sun and moon on the opposite limbs of the earth, may tend to elongate the fluid belt encircling the earth, but their disturbing influence is so small a fraction (67), when compared with the other disturbing forces of nature, that they might never have been perceptible in the oscillations of the ocean, if other forces had

flected by the composition of these forces, from the right line $P Y$ into the diagonal $P P^1$ of the parallelogram $P G P^1 B$. If the influence of the moon is suspended, and we suppose E to represent the earth, with the pole projected towards the observer, and give a third impulse to the particle P , it will be deflected to the earth at P^2 . If the earth and moon have their respective influences, and we again repeat the impulse on the particle P , it will pass above the surface of the earth at P^3 , by a composition of these forces. The particle P may represent water at the equator on the surface of the earth at P^4 , with a projectile force of nearly 1,040 miles the hour for twelve hours, between the earth and moon to P^5 , by the rotation of the earth on its axis. As the magnitude and velocity of the particle from P to P^3 , may be the same as that of the water from P^4 to P^5 , it would be elevated at P^3 . From P^3 to O , the waters of the ocean are retarded in their onward course, as they have a motion from the moon between these two points, owing to the rotation of the earth. The uplifting forces therefore combine, and form a high tide at P^3 , nearly 45° back from a direct line joining the centers of the revolving and disturbing bodies.

74. As the quantity of matter in the earth, in round numbers is eighty times as great as that of the moon, their common center of gravity is eighty times nearer the former than the latter, and is therefore situated about 3,000 miles from the center of the earth, and is represented at E . The earth completes a revolution around the moon on

the point E, in the same length of time that is required by the moon to complete a revolution around the earth. The mean distance between the moon and point E is invariable, and the motion of the earth around the moon may be said to be hinged on that point. Let the line L N divide the earth into equal sections. In the revolution of the earth on its axis, the section $P^2 P^5 O$ has a motion from the moon, the opposite section $O^1 P^4 R$ having a motion towards the moon.

The distances between the moon and the points Z and N, are not affected by the motion of the earth around the moon: the limbs Z and N must therefore have equal velocities of rotation and translation. The axis of rotation is then equidistant between Z and N, but as the earth is falling around the moon on the point E, the center of the earth C and the limb R are moving in orbits C O^1 and R P. Hence R has a greater velocity towards P^4 than P^2 has towards P^5 .

75. The point in the earth that has the least motion, I shall designate the axis of rotation. That point is not located at the true center of the earth, but somewhat removed from it as is represented at A. As its angular position from a line joining the moon, and the center of the earth remains invariably the same, the retrograde motion of the moon when compared with the rotation of the earth on its axis, causes the axis of the earth to be unstable, giving an eccentric motion to the earth. The longer limb is in the direction of P^4 , the shorter limb towards P^5 , and the greater centrifugal force engendered on

the long limb of the eccentric, forms a high tide at R. The accumulation of the waters at P^3 and their retardation from this point to O, causes an ebb tide at the latter point, and the increased centrifugal force on the long limb of the eccentric, tending to raise the waters at R, has the effect to cause an ebb tide at O^1 . The tendency of the water to flow on from P^3 by inertia, and form a high tide on the short limb of the eccentric at P^5 , is counterbalanced by the decrease in the centrifugal force, which allows an equal flow in a transverse direction towards the poles.

76. If the center of the earth C had as rapid a motion of translation in its orbit C O^1 around the moon, as R has in its orbit R P, the rotating velocity of R towards P^4 would be no greater than that of P^2 towards P^5 . The chord $P^4 P^5$ would then rotate on a true and fixed center at C, or in this condition, as Herschel says, "the rotation must be performed *round an axis* or diameter of the sphere, whose *poles* or extremities, where it meets the surface, correspond always to the same points on the sphere." But this requires that the axis of a revolving body have a fixed position in space, or that every portion have an equal motion of translation, which does not admit of an orbital motion, but requires that the revolving body move in a rectilineal path. The curvilinear path of the moon, with its balanced condition as before described, (58) causes the moon to have an axial rotation, giving alternate day and night to the inhabitants of the moon.

77. When all portions of a body continually mov-

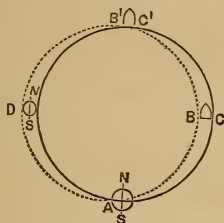
ing in a given direction, have not equal velocities of translation, the resultant is a motion of rotation on an axis, as well as in an orbit, as is evident in the case of the moon.

Let I represent the inferior limb of the moon, and I I¹, the orbit in which it moves when passing around the earth, S the superior limb, and S S¹, its orbit. It is evident that the point S passes around the point I, with each revolution of the moon in its orbit, and as the length of the orbit S S¹ is equal to that of I I¹ plus the circumference of the moon, it is evident that the magnitude of the rotating velocity of S over that of I, is equal to the axial rotation of the matter at S around that of I.

Again, the axis of rotation in a revolving body is located *at a point having the least centrifugal force*, which is represented at I in the moon and at A in the earth. It is well known that solar and sidereal time never agree, and that the variation in a year is just equal to one revolution of the earth on its axis.

As the rotating velocity of the limb S is greater than that of I, the centrifugal force engendered on the superior or longer limb of the eccentric, must exceed that on the inferior limb, for this force increases with the rotating velocity when the periodic times are equal (56). As a portion of the earth is falling towards the moon, as well as the moon towards the earth, the unequal centrifugal force which is proven to exist on opposite limbs of the moon, determines the fact of the existence of unequal centrifugal force on the opposite limbs of the earth.

78. A condition may be conceived, when a deviation from a rectilinear path will not disturb the axis of rotation, as when a projectile is hurled from a rifled gun, or if by chance a planet should move pole foremost in its orbit, and if the centrifugal force engendered by its axial rotation should be sufficient to hold its equator invariably in the same plane, as is represented in Fig. 2. Let B represent



a projectile, as having moved through 90° of an arc of a circle to B^1 . The sides of the ball $B C$ and $B^1 C^1$ will have passed through equal spaces in equal times, as is represented by the dark and dotted lines, as these lines are of equal length and come in contact with the ball at the same points. Or A may represent a planet as having made an entire revolution, in an orbit from A B B^1 and D to the point of starting, N and S representing the axis of rotation, N the north and S the south pole, the pole N moving foremost from A to B^1 , the opposite pole S moving in an opposite direction by D to the point of starting. In this case, the axis of rotation will not be made unstable by the influence of foreign matter, or a deviation from a rectilinear

path, as all portions of the moving mass have equal velocities of translation and rotation. In this example, the surface of the rotating mass is supposed to be uniform, and the density of the opposing limbs equal.

79. When Sir John W. Herschel was introducing the hypothesis of the precession of the equinoxes, into his valuable work on astronomy, he seemed to fear that the motion of the earth as described by him, might lead some of his readers to believe that the axis of the earth was unstable,—which is really the case. He says “the reader will take care not to confound the variation of the position of the earth’s axis in space, with a mere shifting of the imaginary line about which it revolves in its interior. The whole earth participates in the motion and goes along with the axis, as if it were really a bar of iron driven through it. That such is the case is proved by two facts.* Second, that the sea maintains its level, which could not be the case if the motion of the axis were not accompanied with a motion of the whole mass of the earth.” But the ebb and flow of the tides demonstrates the fact that the sea does not maintain its level, and it is partly because the axis is not accompanied in its motion with the whole mass of the earth, producing the tides, on the side of the earth opposite the moon.

80. When we compare the centrifugal force which should be apparent on the long limb of the eccentric, with the centrifugal force which perpetually uplifts and sustains the water on the equator,

* The first will be noticed in the next section.

nearly thirteen miles in height, the tidal wave may seem very inferior to that which we might expect. The fact is, the unequal attraction of the old hypothesis might uplift a tidal-wave a fractional part of an inch, but it is entirely inadequate to the daily observed results. A force vastly superior to that assigned, is required to uplift a wave in the ocean a few feet, as the point at which the tide culminates, changes its position on the equator nearly 1040 miles the hour. And as we proceed in the investigation, the impossibility of arriving at definite conclusions regarding the height of a tidal-wave, in any particular locality on the surface of the earth, by theory alone, becomes evident. Several mathematicians have bestowed great care and patience, on the problem of the flow of water in channels with a given depth, width, and head. But with the irregular depth, the ever-varying direction of ocean currents, and outline of the coast, they would naturally differ as to the length of time it would take the accumulated waters at the equator to flow back towards the poles, and form a perfect sphere, if the motion of the earth on its axis could be suspended with impunity,—although the sea is open in this direction from the vicinity of pole to pole.

Or, how high the water at the equator would be elevated with the existing centrifugal force, if the equatorial plane changed its position in latitude, as many miles the hour, as the culminating point of the tides do in longitude on the equator.

The complexity of the problem becomes still more apparent, when we consider the transverse

position of the continents (50), the ever-varying magnitude of the distances between the sun, moon and earth, with the frequent change in the direction of ocean currents, and in the pressure of the atmosphere.

Again, the unequal velocity and stability of the water to resist the disturbing forces consequent on the axial rotation, varies with the latitude, and currents moving in a northerly or southerly direction in the formation or dispersion of a tidal wave, move more or less in curves, owing to the rotation of the earth on its axis. Having thus noticed a few of the component forces which are manifest in the formation of a tidal wave, the intricacy of the integral problem demonstrates the absolute necessity of establishing the tables of the tides, in different localities, by patient and persistent observation. Without further remarks, I shall assert that the forces which have been indicated in this treatise, as producing the ebb and flow of the tides, are sufficient to produce this result.

The effect of the axial rotation of the earth, together with the influence of the moon, is piling up the waters of the ocean, forming a high tide nearly 45° back of the zenith, while the increased centrifugal force engendered on the long limb of the eccentric, by the instability of the earth on its axis, is throwing it up forming a high tide on the opposite side.

The sun and planets also have an influence. The influence of the sun on the earth's axis, will be noticed more fully in the next section.

81. As the earth has a motion of translation around the moon, on their common center of gravity represented at E Fig. 1, some philosophers have attempted to account for a high tide near the nadir, by the increased centrifugal force this motion may engender. According to this hypothesis, N must be situated on the long limb of the eccentric, (which is not the case), and centrifugal force being a secondary force, must be the most apparent back of the point where the velocity is the greatest, as is seen in the motion of the earth in its orbit after it passes the perihelion, or as is seen in the formation of a high tide at R, nearly 45° back from the longest limb of the eccentric.

Therefore if this motion engendered a high tide at the nadir, it would culminate at O, nearly 45° back of what would in that case be the longest limb of the eccentric, and most rapid motion, instead of at R nearly 45° ahead of the force which would, by this hypothesis, be producing it. As the mean distances between the moon and the points Z C and N are invariable, the earth has no motion towards the moon in that direction, and the unequal attraction of the moon on the earth could not produce the tides at the nadir.

PRECESSION—NUTATION—AND OBLIQUITY OF THE ECLIPTIC.

SECTION IV.

82. The motion of precession was known to the ancients, and modern works on Astronomy have made the subject familiar to every reader. Sir Isaac Newton found strong opposers to his newly discovered theory of gravitation. To silence them and establish fully his theory, he must have felt the necessity of accounting for all the observed motions of the heavenly bodies. The motion of precession therefore called upon him most imperatively for an explanation.

83. He attributed it to the unequal attraction of the sun and moon on the equatorial and polar regions, as there is more matter at the equator than at the poles. The Newtonian theory, which has been adopted by modern astronomers, has some shades of plausibility. When the sun and moon are not in an equinox, their angular position to the redundant matter on the equator, is such that they

84. If the redundant matter on the equator K R D tends in any way to follow the sun and moon, by any superior gravitating force inherent in it, over that of the matter at the north pole E, the angular position of the sun and moon to the redundant matter on the equator, is such that the tendency would be perpetually to move the pole nearly in the same direction, diminishing the obliquity of the ecliptic until they would coincide. For the action of the sun and moon on the matter K D, would tend to draw the point R into the plane of the ecliptic, elevating the south pole and depressing the northern, and when they were south of the equator, as represented by $M^2 S^4$, the motion of the poles would be in the same direction, for the action of the sun and moon would tend to draw Q into the plane of the ecliptic, still elevating the south pole S and equally depressing the northern. When the sun and moon are in the equinoxes there is no tendency to motion in either direction.

But that the poles of the earth have not a motion in the same direction tending to diminish the obliquity of the ecliptic, was fully proved by Bradley, ten years after Newton's death. He found that stars situated near the solstitial colure, that were almost opposite in right ascension, appeared at times to advance north and south, proving a nutation of the earth's axis, as if, (viewed by Newton's theory), the moon in certain sections of its orbit repulsed rather than attracted the redundant matter at the equator.

85. In continuing the investigation respecting

the Precession of the Equinoxes, the fallacy of this hypothesis is still more apparent. It is said that the action of the moon on the accumulated matter at the equator, causes the poles of the earth to be “describing a circle in the heavens around the pole of the ecliptic as a center.”

Let E L represent the ellipse in which the North pole is moving, and Q R the equator. When the north pole E arrives at L in the ellipse, the equator it is said would be inclined from its former position Q C R to that designated by the dotted line Q A R, causing the sun to cross the equator in a new position represented at A on the dotted line, instead of at C on the line Q C R, its former point of intersection, causing the point where the sun crosses the equator to move a few rods to the westward at every intersection, producing what is known as the Precession of the Equinoxes. According to this hypothesis, when the pole in its circuit E L arrives at the opposite side of the ellipse represented at N², the equator must be tipped from its original position equally in an opposite direction represented by the dotted line Q V R. If in the former case, the variation in the inclination of the pole causes the sun to cross the equator in a new position, at A, a few rods west of the point where it previously intercepted it at C, in this latter case, it must cause the sun to intersect the equator in a new position, at V, on the dotted line Q V R, a few rods east of its previous point of intersection. In this case, the motion of precession must be reversed, while the

87. Let us take a northern position in the heavens on a line with the center of the earth C , as is represented in Fig. 4, the moon M being in conjunction with the sun S , and the sun in the vernal equinox, and project a perpendicular line L from the sun, through the center of the moon and earth.

The axis of rotation in the earth is represented at A in this figure, and holds the same angular position to the center of the earth C and line L , as in Fig. 1. If we note the motion of the earth and moon as they move on in their yearly course, we find that when the earth has completed one revolution in its orbit, the moon has made nearly thirteen in its orbit, falling a fraction of time back from the perpendicular line L to M^1 . Let us now project a second perpendicular line L^1 , from the center of the earth to the moon M^1 . The axis of the earth has fallen back and is at A^1 , maintaining the same angular position to the center of the earth and latter line L^1 , that it did from the former line L .

The influence of the moon on the earth, as has been shown, (75,) causes its axis of rotation to be removed from the geometrical center of the mass, giving an eccentric motion to the earth. The retrograde motion of the moon when taken in connection with the diurnal rotation of the earth, causes the earth's axis to be unstable, as it is continually dropping back to meet the moon. The earth arrives at its starting-point in the heavens at the end of its yearly revolution, but its surface is held back by the eccentric motion, caused by the instability of its axis.

88. Astronomers have stated that the variation of the equinoctial points is not uniform, and that the obliquity of the ecliptic is diminishing, without clearly defining the cause, or limits of these variations. I will attempt to point out the position of the heavenly bodies, when the variations are the greatest and the least, to verify which would require patient observation through a long period of time. When the influence of the moon reaches the center of the earth from the point M^2 , the axis of the earth is at A^2 . The short limb of the eccentric is now passing under the sun, and when the influence of the moon reaches the earth from the point P , the axis is at A^3 , and the long limb of the eccentric is then passing under the sun.

89. When the short limb is approaching the sun, the falling back of the surface is decreasing from year to year, through a portion of its circuit, and when the long limb is approaching the sun, there is an opposite result.

If the moon represented at M^1 , at the end of the year, came up to the point M from which it started at the commencement of the year, the axis A^1 would come up to the point A from which it started: in that case there would be no yearly precession. Or in other words, if the moon made any exact number of revolutions in its orbit, while the earth was making one in its orbit, the point 2 on the surface of the earth would have returned to 1, the point of starting, for at this point all portions of the earth have had equal motions of translation, and even rotations. But as the moon fails to come up to its

starting-point at the end of the year, the axis represented at A^1 does not come up to the point A , and the dotted line 2 fails to come up to the dotted line 1. The distance at the end of the year between these two lines, where they intersect the surface of the earth, is the amount of the yearly precession. The distance between these lines varies more or less from year to year.

90. Astronomers have asserted that the precession of the equinoxes for different equal periods of time, is not a constant quantity. This is the case, as the surface of an eccentric passes unequal spaces in equal times. When the sun and planets act in conjunction with the moon, or when the distances between them and the earth are diminished, the axis of the earth deviates more from the true center of the earth, and the eccentricity is increased, and vice versa.

The yearly retrogradation of the equinoctial points is maximum, when the influence of the moon reaches the earth from the point P , if the planets act in conjunction, and are at their least distance from the earth, as the longest limb of the eccentric is then passing under the sun. It is minimum, when the moon has its greatest distance from the earth, and is in opposition to the sun and planets, the latter having their least distance from the earth. The angles between the axes $A A^1$ and the sun and moon in these positions, are such that the lines 1 and 2 approach very near to each other. But this distance is diminished, when the axis is at A^4 and the lines 1 and 2 fall on that side of the center of

the earth, as when the moon is in opposition to the sun.

The instability of the earth's axis depends mainly on the disturbing influence of the sun and moon, for the independent influence of the planets must be very slight.

91. In advancing the theory of the stability of the axis, Herschel says, "The whole earth participates in the motion, and goes along with the axis as if it were really a bar of iron driven through it." "That such is the case," he says, "is proved by two great facts: 1st, that the latitude of places on the earth, or their geographical situations with respect to the poles, have undergone no perceptible change from the earliest ages." Though the axis is unstable, its variation may not have been detected, for if the moon made an exact number of revolutions in its orbit, while the earth made one in its orbit, the axis would seem to have undergone no change at the end of the year, for while the axis had continued to drop back to meet the moon, it would have fallen back to its point of starting.

But as the moon does not come up to its starting-point at the end of the year, the axis drops back to meet it in a very diminutive irregular ellipse, nearly the same distance that the equinoctial points drop back to meet the sun, completing a retrograde circuit, with each cycle of the moon.

When the influence of the sun and moon reaches the center of the earth through either of the equinoxes, the poles have an equal motion in space.

92. Thus far in these investigations, the influence

of the disturbing bodies has been considered as reaching the center of the earth, through the plane of the equator. The precession of the equinoxes would therefore exist, if the sun, moon, and planets were perpetually in this plane, whether the earth were solid or fluid, or had a thick or thin crust; whether it was spherical or had its present figure.

If we could view the axis of the earth from the equinoctial point I Fig. 4, it would be situated at A at the extremity of the dotted line I A, and at right angles to it. In this position the poles are equidistant from the moon, and have an equal motion towards that satellite. When the influence of the moon reaches the center of the earth through either hemisphere, that hemisphere is partially in the short limb of the eccentric, and the opposite hemisphere is equally in the long limb.*

93. The inclination of the earth on its axis and motion in its orbit, cause the influence of the sun and moon to reach the center of the earth through the northern or southern hemisphere, except when they are in one of the equinoxes. They are represented as being in the summer solstice, and reaching the center of the earth through the northern hemisphere in Fig. 3. (83) Let Q R represent

* This causes the ebb and flow of the tides on the long limb of the eccentric, at the nadir in the opposite hemisphere from the disturbing body.

The tidal forces would be rapidly decreasing in the higher latitudes, in consequence of the less rapid axial velocity, were it not that the stability of matter to move in a given plane decreases with the velocity, and the points at which the tides culminate change their position less rapidly.

the plane of the equator, and M C the ecliptic. The south pole S is partially in the long limb of the eccentric, and has a more rapid motion towards the moon than the north pole E, which is partially in the short limb. If the influence of the sun and moon was removed from the earth, its path in the heavens would become rectilineal, and its axis of rotation would occupy the center of its figure. With a given axial velocity, the more rapid the deviation from a right line, the further would the axis be removed from the center of the figure.

94. When the sun is in the summer solstice as represented in Fig. 3, the south pole, being partially in the long limb of the eccentric, has a more rapid motion towards the moon than the north pole. The deviation of the axis from the center of the earth in the southern hemisphere, may be represented as moving from S^2 to S^3 , when the moon is passing from the vernal equinox to the autumnal, while the axis may be represented as deviating from N to N^1 in the northern hemisphere. When the moon is passing from the autumnal to the vernal equinox, the deviation would be from N^3 to N^2 in the northern hemisphere, and from S to S^1 in the southern.

95. If the moon was 90° back from its present position, the line of the axis would fall between the lines $S^1 S^3$ and $N^1 N^3$, and when the moon was at the nadir, reckoning from its last position, the axis would fall between the lines S S^2 and N N^2 . The point where the direct line which joins the moon with the center of the earth, intercepts the line

which represents the axis, may be termed the hinge-point. When the influence of the sun and moon reaches the center of the earth through either hemisphere, the hinge-point is located in that hemisphere, and when through the plane of the equator, the hinge-point exists in that plane. The inclination of the earth's axis to the ecliptic, together with its orbital motion, causes the hinge-point to move north and south, elevating or depressing the poles, increasing or diminishing the obliquity of the ecliptic.

96. When the disturbing body crosses the equator, the pole that was depressed becomes the elevated pole, and vice versa, producing what is known as the nutation of the earth's axis. This would restore the pole to its former position, if the moon was the only disturbing body, and if it held the same position and distance from the earth at the end of the year, that it did at the commencement, instead of causing the poles to deviate perpetually in the same direction, as they must if the motion was produced by the action of gravity on the redundant matter at the equator, according to Newton's hypothesis.

The stability of matter on the equator to move in a given plane, in consequence of the axial rotation, combines with the motion of nutation, and the resultant of these forces tends to equalize the circuit of the poles in space. The moon thus far has been considered the only disturbing body. The sun and planets have their independent influences, and at times they act more or less in unison, caus-

ing the instability of the earth's axis to vary in the opposite hemisphere, and the poles of the earth to move in an undulating irregular elliptic circuit in the heavens, around the pole of the ecliptic.

97. The obliquity of the ecliptic is greatest when the sun is near an equinox, if the sun, moon, and planets act in conjunction, and have their greatest northern or southern declination and least distance from the earth when they pass the Winter or Summer solstice, for in this condition the hinge-point approaches the equator with the equinox, from its extreme northern or southern limits. The obliquity is least when the sun and planets are in opposition to the moon, and have their least distance from the earth; the moon having its greatest distance and least declination when the sun passes the Summer or Winter solstice, for in this condition the hinge-point deviates least from the plane of the equator.

98. The return of the poles of the earth to a given point in the heavens, and of the plane of the equator to a given position when compared with the ecliptic, depends on the return of the sun, moon, and planets to a given position in the heavens, when compared with the center of the earth.

The upheaval of a mountain, "any where between the pole and the equator," will not "cause the poles to wander about" sensibly from their true position, as asserted by Newton in the Principia, for the inequalities on the surface poise each other (33).

The diurnal instability of the earth's axis, is visible in the motion of the tides. The effect it has

on precession and nutation, has long entered into the calculations of astronomers, and when we consider the changes of azimuth noticed in the coast survey, and the increasing perfection in the way of observation, we may hope that the diurnal instability of the earth's axis will soon be considered, in astronomical calculations.

SECULAR ACCELERATION OF THE MOON'S MEAN MOTION.

SECTION V.

99. When Dr. Halley, and others, compared the records of the ancient Chaldean and Arabian astronomers with more modern lunar tables, they considered the fact fully established, that the periodic time of the moon's revolution is sensibly shorter in modern times. The physical cause of this acceleration greatly perplexed astronomers, through a portion of the eighteenth century.

The French Academy of Sciences at Paris, ever zealous to advance the cause of science, offered their prize of 1770 to induce a thorough investigation, to ascertain if it could be accounted for by the theory of gravitation. Euler, one of the first mathematicians of the age, received the prize, but he was unable to solve the problem. He says, "there is not one of the equations about which any uncertainty prevails, and now it appears to be established by indisputable evidence, that the secular inequality in the moon's mean motion cannot be produced by the force of gravitation."

Earnestly desiring a solution of this intricate problem, the Academy of Science continued to offer its stimulating prize.

Euler extended his researches and confirmed his previous declaration, saying at the same time, "that no doubt henceforth could exist that the inequality arose from the resistance of an ethereal fluid pervading the celestial regions." The resistance it was said would "*lessen* her *centrifugal force*. The earth would consequently draw the moon closer to herself, thus diminishing the magnitude of her orbit and decreasing her periodic times."

Others investigated this interesting and perplexing subject, and received the prize. But none were able to account for the acceleration, by the theory of gravitation.

100. While the scientists were thus becoming skeptical on the theory of gravitation, Laplace remained a constant believer in the theory. He may therefore have felt that necessity was laid upon him to assign the physical cause. Herschel says: "It was in this dilemma, that Laplace once more stepped in to rescue physical astronomy from its reproach." And it seems that Laplace ended the controversy, by introducing as the cause the hypothesis, "that it depends on the secular variations of the eccentricity of the earth's orbit." He found that "the action of the *planets* produced nothing of the kind." The disturbance he therefore traced most fully to the sun.

101. But how can the sun "transmit," or as he

says "reflect" back to the moon the action of the planets, so as to effect its periodic times, without affecting the periodic time of the earth, as the earth is a near neighbor of the moon ; the orbits of each being concave towards the sun, and the moon's orbit when viewed from the sun dwindles nearly to a point, as the orbit of the moon is only about one-half the diameter of the sun.

The mean distances of the moon from the earth, and the moon and earth from the sun, depend on the centrifugal and centripetal forces, as these forces poise each other. That these forces are constant between the sun, moon, and earth, is proved by the permanency of the periodic times of the earth.

On account of the constant variation in the position of the planets, any "transmuted" or "reflected" action from them through the sun, would impart irregular motions to the earth. That this is not the cause of the acceleration of the moon is proved by the fact, that it does not equally affect the motion of the earth. If the power to accelerate springs from the sun, according to Laplace's theory, may it not be proved to be in some way inherent in that mass, instead of being "reflected from the planets." As the planets are poised between the centrifugal and centripetal forces (119), if the attraction of the earth on the moon was in any way decreasing, the length of the moon's orbit must be increasing, and its periodic time must be decreasing, instead of being accelerated.

As the force of gravitation in the sun, moon and earth is stable, the mean distances of the earth and

moon from the sun, and the mean velocities in their orbits, must be invariably the same.

102. As the irregular velocity of the earth in its orbit, as well as its distance from the sun, depends on the centripetal and centrifugal forces, it has its mean distance from the sun (95,000,000 of miles more or less), at the point in its orbit when it has its mean motion. For when the magnitude of the distance is greater than the mean distance, the velocity is less than the mean velocity, and when the distance is less, the velocity is greater. The mean velocity and distance of the earth from the sun in its elliptic orbit, would be its invariable distance and velocity, if its orbit should conform to a circle.

The mean radius-vector of the earth in the elliptic orbit, would be the invariable radius of the circle. The mean distance of the earth from the sun is equal to one-half of the transverse axis of the ellipse. The circumference of the circle must therefore be longer than that of the ellipse; then if the earth's orbit is conforming to a circle, its mean motion must be increasing, or the periodic time of the earth would be decreasing.

103. The orbits of some of the comets are such elongated ellipses, that, should they conform to a circle, their orbital velocity must be very greatly increased, or else their periodic times must be greatly decreased, as there is no increased force to accelerate the velocity. We must consider that the periodic times of planets would be decreasing if their orbit should conform to a circle. This might seem to conflict with Kepler's 3rd law, if

that was not based on the 1st, that “the planets move in ellipses, &c.” If the length of the year would be increased if the earth’s orbit was a circle, it would be increasing in length if it was now conforming to a circle. That a variation in the form of the earth’s orbit might affect the periodic time of the earth, is evident from Kepler’s second law, for the mean radius-vector is invariable, whether the earth is moving in the circle or the ellipse and by his law, must describe arrears proportioned to the times.

If the form of the earth’s orbit is continually vibrating between a circle and an ellipse, as it is said to be, and the periodic time of the earth is equal in the circle and in the ellipse, the arrears described cannot be proportioned to the times, as the circumference of the circle is greater than the ellipse. The discrepancy of several millions of miles, existing between authorities regarding the mean distance of the earth from the sun, indicates the impracticability of determining by observation the exact distance of the planets from the sun, or the slight effect the peculiar form of any planet’s orbit may have on its periodic time. The entire correctness of Kepler’s laws has many times been called in question. Laplace said, “they are very nearly observed in the motion of the satellites.” Herschel says, “we learn to regard the laws of Kepler as only *first approximations* to the much more complicated ones which actually prevail.” Again, if the earth’s orbit is gradually conforming to a circle, the unequal distance, orbital motion,

and unequal apparent diameter of the sun, in the aphelion and perihelion passages of the earth, must be gradually becoming equal.

According to this hypothesis, the motion of the earth must be such that the sun must be approaching the center of the orbit, for the unequal attraction of the sun on the earth in the different sections of its orbit, must cause unequal orbital motion which does not admit of a circular orbit.

104. The orbits of the planets are subject to perturbations by the effect of each on the other, but this does not warrant the assertion that the eccentricity of the earth's orbit "is and has been since the earliest ages diminishing, and this diminution will continue, (there is little reason to doubt), till the eccentricity is annihilated altogether, and the earth's orbit becomes a perfect circle." Were this to prove true, it would annul Kepler's first law, and the earth would then have an orbit unlike any of the planets, since astronomers have studied the motion of the heavenly bodies. "The time required for these evolutions," Herschel says: "has not been calculated," which is *most undoubtedly true*.

If the earth's orbit is gradually conforming to a circle, it is increasing in length; then as the moon's orbit encircles the earth its length must also be increased. If the earth's orbit can undergo this change in form, increasing in length without affecting the periodic time, it is impossible that increasing the length of the moon's orbit under these conditions, can diminish the periodic time of the moon.

105. The secular acceleration of the moon's mean motion, has been attributed to "the resistance of an ethereal fluid, pervading the celestial regions." If there was any resistance in ethereal space which affected the periodic time of the moon, its effect would be manifest on the periodic times of the earth, and other planets. But as this has at times been strongly asserted, I will notice this fallacy more particularly in the next section. Although there are valid objections to all of the theories advanced to explain the secular acceleration of the moon's mean motions, the existence of the secular inequality has been demonstrated by incontestable evidence. The *very* cause of the acceleration of the moon's mean motion, therefore becomes an exceedingly interesting question.

106. Laplace, with others, examined the lunar theory, with the most scrupulous attention. He decided fully that the action was from the sun. If he had considered the disturbing effect of the sun on the earth's axis, instead of the "reflected" action of the planets from the sun, he would have discovered the physical cause. By the law of gravitation all matter in the universe attracts all other matter, and is itself equally attracted.

The various positions and unequal attraction of the planets on the sun, when acting in conjunction with matter outside of the solar system, shows that the sun must have more or less motion in space.

The very slow and unequal rotation of the line of the apsides (62), indicates the more or less curvilinear translating motion, with unequal periodic

times, of the central masses, around which the heavenly bodies are revolving. This motion is, in a measure, analogous to the rotating motion of a vibrating pendulum, so beautifully illustrated by Foucault a few years since.

Astronomy gives many indications that the sun has a proper motion in space. According to Herschel's calculations, it is moving at the rate of 422,000 miles per diem. The sun then, as well as the moon, does not hold the same position at the end of the year, that it occupied at the commencement.

107. In explaining the physical cause of the tides, and the Precession of the Equinoxes, it was shown in Figs. 1 and 3, that the deviation of the earth from a right line caused by the gravitating force of the sun, moon and planets, caused the axis of rotation to be removed from the true center of the mass, giving an eccentric motion to the earth. The independent disturbing effect of the moon on the earth's axis, (as may be seen at $M^2 A^2$ Fig. 4), tends to maintain a limb of the eccentric of uniform length, invariably turned towards itself, and causes limbs of variable lengths to be passing under the sun. The disturbing effect of the sun is, the same in kind, but less in degree. When the sun acts in conjunction with the moon, the length of the short limb is diminished, increasing the longitude of the moon, and vice versa.

108. If the sun held a fixed position in the heavens, this disturbance would be compensated at the end of the year, for while the moon would have

been apparently accelerated in one section of its orbit, it would have been retarded equally in the opposite section. In this case, no disturbance of the earth's axis caused by the sun, could be detected at the end of the year.

As has been shown in regard to precession (89), if the moon held the same fixed position at the end of the year that it did at the commencement, there would be no yearly precession. But the longitude of the sun and stars is increased, by the independent disturbing effect of the moon on the earth's axis, and the moon is accelerated by the disturbing effect of the sun on the same.

On account of the uncertain data respecting the proper motion of the sun in space, and the complex influences of the planets, it may be impossible to determine whether the effect of the sun and planets, on the earth's axis, would produce the amount of acceleration which observation has established, of about $11''$ in a century.

109. Herschel says "the earth's orbit will become a perfect circle, the tables will be turned, and the process of ultimate restoration will commence, after which it will again open out into an ellipse, the eccentricity will again increase, attain a certain moderate amount, and then again decrease." By this hypothesis, the acceleration will continue while the earth's orbit is conforming to a circle, but when the orbit begins to form an ellipse, it will be converted into a continual retardation.

Laplace says, "Future ages will develop these great inequalities, which are periodical, like the va-

riations of the eccentricity of the earth's orbit, upon which they depend."

The moon's mean motion will continue to be accelerated, as long as the sun does not hold a fixed position in the heavens; and it will never be retarded at any future day, whatever natural variation there may be in the form of the earth's orbit, and the longitude of the sun and stars will continue to increase, as long as the moon accompanies us, in our passage through celestial space.

PRINCIPLES OF PLANETARY MOTION AND ETHEREAL RESISTANCE.

SECTION VI.

110. Sir Isaac Newton decided that any ether, however subtle, would retard motion, and since Newton's day, any apparent inequality in the motions of the planets has, by some, been attributed to the resistance of an ethereal fluid in celestial space.

Hence, some of the believers in the vibratory ethereal propagation of light, have affirmed that the resistance it offered to planetary motion, diminished the magnitude of the moon's orbit, and caused the accelerated mean motion of the moon. Others have compared the trajectory of the moon, to that of a ball, projected from a gun through the atmosphere. In the Principia Book III., Prop. 42, Newton says, that "bodies may, indeed, persevere in their orbits by the mere laws of gravity, yet they could by no means have at first derived the regular position of the orbits themselves from those laws." This theory is universally adopted, I believe. Robinson says, "we perceive that the eccentricity of orbits, and mean distances from the sun, depend on the amount, and direction of the origi-

nal impulse or velocity, which the planets have in some way obtained, and it is not necessary that the planets should have any definite impulse, either in amount or direction, if the direction is not directly to or from the sun." I shall invite your attention in this section, to a few brief remarks on the laws of planetary motion, and shall demonstrate the fallacy of a resisting medium in celestial space, and show that the direct force of gravitation to and from the sun, may primitively have produced planetary motion.

III. When explaining the system of the world in the Principia, Newton prefixed a diagram, showing that if a body on a lofty mountain, have an impulse in a horizontal direction, sufficiently rapid to poise the force of gravitation, and return the body to the point from which it was projected, it would continue to revolve around the earth in an orbit similar to that of the moon.

Or if a body when "projected in free space," is "exposed to the action of a central force, varying according to the inverse square of the distance," it would revolve in a circular orbit, "which would be one of the conic sections."

That Laplace considered this primitive impulse transverse to gravitation necessary, when he introduced his famous genetic hypothesis of the solar system, is evident from his remark. "The inertia of matter is most remarkable in the motions of the heavenly bodies, which, during a great many ages, have not suffered any sensible alteration." He considered that the nebulous matter originally ex-

isting in space, extending far beyond the orbits of Neptune, being condensed into a rotating spheroid, threw off rings by centrifugal force, from time to time, as the rotation became accelerated by the gradual condensation. The rings being sustained in their elevated positions, by the centrifugal force which uplifted them, were left behind becoming ruptured, and contracted upon themselves and formed planets. The original rotating velocity of the rings, gave the planets their primitive impulse, transverse to gravitation.

If the nebulous matter composing the solar system was condensed into a single rotating spheroid, there would be no foreign matter in the solar system, to cause any axial disturbance or resistance. If this theory was correct, the axis of the rotating uplifted circular rings, would be parallel with the axis of the central rotating mass. The axes of the planets should therefore be parallel, and perpendicular to the plane of the ecliptic, but on the contrary, some of them, as is the case with Venus, are greatly inclined. As the rings uplifted by centrifugal force must have been perfectly circular, the orbits of the planets would have been circles, instead of ellipses, as established by Kepler's first law. If they were originally hurled from a single rotating spheroid into space, their orbits should be parallel in a given plane, instead of varying as they do, more than 34° , and some of the satellites more than 78° .

One of the important evidences mentioned by Laplace in substantiating his genetic theory, was

“that the planets rotate in a direction the same as that in which they go round the sun, and on axes approximately perpendicular to their orbits, which, since he wrote, has been contradicted in the case of Uranus, and still more recently in the case of Neptune.”

112. According to this hypothesis, when the superior rings were thrown off, they must have been of enormous circumference, gradually decreasing to the more inferior rings. It seems impossible, that an uplifted ring could contain the vast amount of matter found in Jupiter and its moons, and the next rings be sufficiently slender to form the asteroids, and the next ring uplifted contain sufficient matter to form our earth and accompanying satellite.

The asteroids must have been formed of independent rings, as they must have been uplifted in perfect circles. If they had been fractured in subdivisions, they must have contracted upon themselves and formed a single mass, as would a ring with a single fracture. If the rings which accompany Saturn in his course through the heavens, were uplifted from the body of the planet, they must be uniform in density and distance from the body of the planet, through their entire circumference. For the matter could not have been uplifted if it was not free to move, and centrifugal force would not uplift matter in this condition, that was not uniform in density. The stability of the rings of Saturn in their orbits, indicates that the elements do not answer the conditions necessary for the ring hypothesis.

If the orbits of some of the satellites approach so nearly to circles that their motion might be explained by the ring hypothesis, their axial rotation demonstrates that it is not the case, for it is said that the unequal axial rotating velocity of the inner and outer portions of the rings, gave the planets their axial rotation. If so, a similar motion must have been imparted to the satellites, but when we consider their unequal masses, and the axial rotation which must have been produced by the ring hypothesis, it does not agree with their actual axial rotation, which is caused by their balanced condition. (58) Kepler's first law demonstrates that the matter of which the planets are formed, could never have moved in circular orbits; and comets traverse indifferently almost every point in the heavens. The fallacy of the ring hypothesis is evident, when we compare the rotating velocity of the equator of the central mass, with the orbital velocity of the nearer accompanying secondary. For instance, by the ring hypothesis, when the ring or planet mercury was thrown off, the sun must have reached to the orbit of mercury, and its equatorial axial velocity, must have agreed with the orbital velocity of that planet, which is nearly 110,000 miles the hour; then, as the sun must have contracted, it is well known that its rotating velocity must have increased, and centrifugal force increases with the velocity and periodic time, but instead of such increased velocity, which would have caused fragments of the sun to fly off into space, the equator of the sun has a velocity of only about 4,500 miles the hour.

An impulse "in the direction of lines parallel to the horizon," as set forth by Newton in his diagram on the system of the world, and in our text-books generally, would be necessary to project a body from the earth, and cause it to "go on revolving through the heavens," in an orbit like the moon, as the body has an equal translating velocity with the earth. But an impulse parallel with the surface of the sun or primaries, was not necessary in the genetic elements of the planets.

113. As the density of matter (3) depends on the conditions determined by the force of gravitation, matter must have existed prior to its condensation, in a gaseous or nebulous form, and this primitive condition coincides, I believe most fully, with Moses' account of creation in the book of Genesis. From that we learn that the heavens and the earth had a "beginning," that the matter of which the earth is composed "was without form," indicating that it was a very rare fluid, to us a "void," and darkness was upon the deep "abyss of celestial space, until the Spirit of God moved, (by the agency of gravitation) upon the face of the waters," or fluid, to condense it, (19) "and there was light." (65) When the surface of the earth became refrigerated and opaque, "God divided the light from the darkness," but the length of time intervening is not specified. "And God called the light day, and the darkness he called night. And the evening and the morning were the first day," or period. (48) For Peter says, "But, beloved, be not ignorant of this one thing, that one day is with

the Lord as a thousand years, and a thousand years as one day."

It was necessary that the fluid, or "waters which were under the firmament," should be "divided from the waters which were above the firmament," in the formation of the solar system from nebulous matter. After the waters were thus divided, and the planets formed, "God called the firmament," or celestial space, "heaven."

The primitive condensation would cause a high surface temperature. (19) The water was held in suspense, until the surface refrigeration formed mountains and valleys (21), as we are told, "there went up a mist from the earth, and watered the whole face of the ground." When the surface temperature became sufficiently reduced to allow the suspended fluids to be condensed, "the waters under the heaven were gathered together unto one place, (in the depressed portions of the earth), and the dry land appeared." When the overhanging mist became condensed, the "lights" were set, or became visible, in the "firmament of the heavens, to give light upon the earth," "to divide the day from the night; and they were for signs, and for seasons, and for days, and years." The 1st verse of Genesis, in an introductory way, speaks of the creation of the heaven and earth. The 2d, 3d, 4th and 5th, speak more particularly of the creation of the earth. The 6th, 7th and 8th, pertain to the creation of the solar system. The 9th, 10th, 11th, 12th and 13th again speak of the earth, the 14th, 15th, 16th, 17th and 18th, of the earth and the

appearance of the solar system, after the surrounding mist or waters had been gathered together into one place. The last named verses determine the division of time into seasons, and days and years, as we have them now, except that the length of the day has somewhat decreased, since the fourth day or period of creation, by the refrigeration and contraction of the earth, which took place in the early periods of the earth.

We are therefore induced, by revelation as well as by science, to believe that the matter of which the earth and planets are formed, originally pervaded space in homogeneous nebulous form. If the density of the solar system is calculated by this theory, a square mile of such matter would weigh less than a cubic inch of our atmosphere, and might well be called a "void."

114. How improbable that matter having this great tenuity, should offer sufficient resistance to the falling particles, to cause the mass to rotate with a velocity sufficiently rapid, to engender the centrifugal force, necessary to uplift rings of sufficient magnitude to form the planets.

As gravitation was an active force "in the beginning," stellar and solar motion was coeval with gravitation. Planetary matter which was scattered through space, must have formed in independent rotating bodies, as the form and orbital velocity of the planets indicate ; and when we consider the law of gravitation, in connection with the proper motion of the solar system in space, it becomes evident that the matter of which the planets is com-

posed, could not have formed in a single mass as indicated by the ring hypothesis.

An unequal gravitating impulse of the nebulous matter in a curvilinear path, towards some foreign point in space, when taken in connection with an unequal impulse towards the center of the system, would cause continually decreasing circular motions, in the solar system. This tendency of all matter to rotate in a given direction, consequent on the curvilinear motion of the solar system, is indicated by the tendency of any number of independent pendulums, all tending to rotate in a given direction. (106.)

The secular acceleration of the moon's mean motion (108), is a proof of the solar motion in space.

115. Let a line be projected through the center of the solar system, in the direction of the right motion of the sun. Let a second and third line pass across the diameter of the solar system, from opposite directions all in the same plane, passing through the center of the system at right angles to each other, inclined 45° from the first line, with their extremities pointing toward fixed stars in the distant heavens.

For illustration, let the moon, earth, and sun, for the moment represent particles, or masses of matter, freed from gravity and at rest. Let them be located in the above order, on the second or third line, their distances being greater, than that of the sun, from any foreign matter, toward which the whole system is moving ; their present distance from each other

being greatly enlarged, and the sun, representing the center of the system, poised in its position by matter resting on the opposite extremity of the same line; then by the application of the direct force of gravitation, the present planetary motion would be produced. As the sun is poised in the center of the system, its path would be only slightly curvilinear in the direction of the foreign matter, and the earth and moon would move towards the distant mass, less rapidly than the sun, owing to their greater distances. The original influence of the sun on the earth, and of the sun and earth on the moon, would give the earth and moon an impulse toward the fixed star, on the opposite end of the same line. As the earth and moon retain this original impulse towards the fixed star, as well as all succeeding impulses, their paths are not rectilinear towards the fixed star, nor do they move in a right line toward the ever-varying sun. But a composition of these diverging impulses, causes them to be falling in curvilinear paths; the moon towards the earth, and the earth and moon towards the sun, with unequally accelerated velocities, according to the unequal force of the gravitating impulse, caused by their unequal distances from the foreign matter, and from the center of the system, until the centrifugal force poises the centripetal. Hence, the elementary motions of the planetary and stellar systems could have been produced by the direct force of gravitation.

The nebulous matter was primitively distributed uniformly through celestial space. When gravita-

tion was originally imparted to the matter in the solar system, atom attracted atom, and as they formed larger particles, and these formed masses, they were each propelled towards all other matter. As the nebulous matter in the solar system was unequally attracted towards a foreign point, and towards the center of the system, it must have formed in clusters and masses, and moved in curves. The particles located on the line which passes through the system, and points in the direction of the right motion of the sun, must fall into the central mass, as they move nearly in a right line. Those lying on a right line projected through the system at right angles to the first line, as their motion of translation agrees with that of the sun, or central mass, would fall into that luminary. Hence the magnitude of the sun.

116. If we again divide the solar system into four parts, the first and last mentioned lines marking the division, the more central portion of these divisions indicates the distance from the sun, where the masses next in size would accumulate, answering to Jupiter and Saturn. The greater length of the orbit, and the space passed over by the superior planets, indicates that their mass should exceed those of the inferior planets. As their distance from the central mass increased, particles would be attracted and rotate around the larger mass, agreeing with those of the planets having satellites.

117. As the matter was originally distributed uniformly through celestial space, the larger masses not only received the larger number of atoms, but

they fell a greater distance, with accelerated velocity, which would have caused the larger planets to have the more rapid axial velocity. But it is not so with the sun; as the point around which it is revolving is far in the distance, its path is nearly in a right line. It received large accessions of atoms lying in its nearly rectilineal path. As these fall nearly in a right line, the dimensions of the sun would be greatly increased, without materially increasing its axial velocity; while others falling in any direction on a line at right angles to the first line, also unite with the sun without tending to increase its axial rotation.

118. When falling bodies of nearly equal dimensions, as was originally the case, approach each other, the centripetal and centrifugal forces are increased; they have a tendency to rotate around each other. If they unite, it would be on a line, approaching a tangent.

The equivalent of the resisted force of the falling bodies, would be found in their increased axial rotation, and temperature. As the density of matter depends in a measure on its volume, the unequal mass and density of the accumulating bodies, gave unequal density to the opposite portions of the combining mass, as is seen in the motion of the satellites, and as may have been the case with the rings of Saturn. Aside from the central mass, the smaller the body, the less is the original tendency to an axial rotation (117); and the nearer the satellites are to the primary, the more unequal is gravitation on the opposite limbs. (58) Thus the

denser limbs of the satellites, were originally poised towards the primaries. Without considering the effect the particular form of a planet's orbit may have, on the periodic time of the planet, (103) we may say that the permanency of these varying forces and motions, admits in a general sense of the application of Kepler's laws. Thus, as the direct force of gravitation undoubtedly was the genetic impulse in the formation of the solar system, homogeneous, nebulous matter originally fell from a state of rest, and finally formed in masses, or in rings, as in the system of Saturn. As they originally fell by centripetal force, with accelerated velocity, from unequal altitudes towards two common centers, until arrested by centrifugal force, they caused the orbits of the planets to be more or less elliptical, (depending on the original position of the matter), and the primary, to be located in one of the foci.

119. The centripetal force and the velocity increase, as the distance between the bodies is diminished, and centrifugal force increases with the increased velocity of the bodies, or diminished circumference of the orbit. Hence, the nearer the body to the primary the more rapid is its orbital velocity, and *vice versa*, causing the radius-vector to describe arrears proportioned to the times.

Gravitation, or centripetal force is continually tending to bring the secondaries to the primaries, and centrifugal force is continually forcing them away from those centers. The unequal translating velocities of the planets in the different portions of

their orbits, depend on these forces, instead of any inertia that may have been imparted to them at creation. (111) This is indicated by the motion of comets. As they recede from the sun, their motion becomes sluggish and they come nearly to a stand-still, their motion of inertia being nearly suspended at this point, by the gravitating force of the sun. In the early genetic day of creation when the particles first formed in clusters, they may have traveled in all directions in space. But as there is a tendency to rotate in a given direction (106), they were mainly hurled in that direction as is seen in the motion of the planets, and as would be the case with any retrograde comet, should it in any way get entangled with the planets. The union would increase permanently the density and surface temperature, and might increase the rotating velocity of the planet.

If the resultant of their translating velocities, was less than the velocity of the planet, the planet would fall nearer the sun, the centripetal and centrifugal forces would be increased, which would increase the velocity and diminish the periodic times of the planet. This may account for the planets being generally nearer the sun than are the comets, with orbits more nearly circular.

When the planets first took their form, they may have moved more or less in a transverse direction from the present plane of their orbits, but as the larger and more central masses gravitate more powerfully in a transverse direction from the action of the centripetal and centrifugal forces, the orbits

of the planets and satellites have approximated to a given plane, and their axes to parallelism.

120. The discovery of the three great laws of planetary motion by Kepler was sublime, as also was Newton's law of gravitation, to account for them. Newton conceived that all matter has the power to attract all other matter, and that this force of attraction decreases inversely as the square of the distance from the center of the earth. He established this law of gravitation, by comparing the magnitude of the deviation of the moon from a right line, caused by terrestrial gravitation, with the time occupied by a body falling through a given space at the surface of the earth. He also considered at great length, (*Principia*, Book II., Section 6 and 7), the effect that a resisting medium has on a falling body, and in his closing remark he says, "the resistance in every fluid, is as the motion excited by the projectile in the fluid; and cannot be less in the most subtle ether in proportion to the density of that ether, than it is in air, water, and quicksilver, in proportion to the densities of those fluids."

It would seem by the number and delicacy of Newton's experiments, that he must have arrived at correct conclusions, but he did not decide fully, whether there be any resistance in space. For when bringing forward the theory of the "*System of the World*," he says, "the celestial motions are scarcely retarded, by the little or no resistance of the space in which they are performed." It may be impossible to decide this question, without ex-

tending the research farther than Newton did, and determining what effect resistance has on a falling body having an axial rotation; for if the ethereal medium had only the effect to retard the planets, their centrifugal force would be diminished, shortening their orbits, possibly without affecting their periodic times. Hence if there were any resistance we should in this case be unable to detect it.

121. In the case of the moon, it has been claimed that the resistance accelerated its mean motion. If Newton was correct in his conclusions, there is no subtle ether in the paths of the planets, whatever there may be near the sun, as their motion is not resisted, or if any does exist, it does not retard the motions of the planets. This is made evident by extending the researches of Newton, to bodies falling through a resisting medium, while having an axial rotation.

By imparting a rotary motion of a few thousand turns a minute, to a solid metallic globe a couple of inches in diameter, and allowing it to fall through a space of thirty-five feet in the resisting atmosphere, I find it deviates more than three inches from a true perpendicular.*

Although the axial rotation, and deviation of the ball from a right line agrees with the axial rotation of the earth, and its deviation from a rectilinear path, the deviation of the earth is not caused by any resistance in space, but by gravity, although if the translating and rotating velocities of the earth

* Balls projected in gunnery from rifles to a superior or inferior level must partake of this lateral or drifting motion.

could be maintained in a resisting medium, it might have its orbital motion without any centripetal force.

The curvilinear path of the falling ball shows that if the translating and rotating velocities were perpetuated, it would move in a very small orbit without any centripetal force, by the resistance of the air acting unequally on the opposite equatorial sides of the rotating globe, at right angles with its motion of translation.

122. According to Newton's theory, if there is any subtle ether, the falling ball must be resisted, and the deviation of the rotating falling ball demonstrates that if the motion of the planets was resisted, their masses, variations in axial rotation and translating velocities in their orbits, are so unequal, that the magnitude of their orbits and periodic times must be unequally diminished.

Their periodic times would not be assignable by Kepler's third law, or by Newton's law of gravitation. The distance between the earth and sun, and the periodic time of the earth, would be diminished, and the distance between the earth and moon would be increased, as would the periodic time of the moon, caused by the unequal dimensions and unequal axial rotations of these bodies. On account of the decrease in the periodic times of Encke's and Fay's comets, Encke assumed that planetary space is pervaded by an extremely rare medium. But as it is demonstrated that the motion of the planets is not resisted, and the orbits of these comets are interplanetary, the decrease in their periodic times cannot be accounted for by that theory. Again

the unequal variation of their periodic times conflicts with the same theory, to account for which it has been conjectured, "that the resistance arises from collision with innumerable small bodies revolving about the sun." That these bodies exist in abundance is evident, but the effect they may have on the periodic time of the comets, cannot be determined by the falling ball.

123. When the matter of the solar system was in nebulous form, and the force which caused particle to attract particle was imparted to it, the planetary system, following nature's laws, took its form, fitted for life.

If the force of gravitation should be removed from the solar system, many prophecies in Holy Writ would be fulfilled. The sun would "become black" owing to expansion, but the moon like the earth (46) would be melted and "become as blood." "And the stars would fall unto the earth, and the heavens depart as a scroll when it is rolled together." Rev. 6.

The expansion of matter in so many conflicting directions would tend to restore rest. Again, if we look out into the starry heavens, the probability that the earth is to be burned up is confirmed. Astronomers have computed that more than fifteen hundred fixed stars have disappeared within the last three centuries. Some of these stars may have become opaque and invisible by surface refrigeration, as is the case with the earth.

Others have given the most indisputable evidence of having been consumed. Their light has broken

forth with such splendor, that they could be seen at noonday by the naked eye, and at night through a canopy of clouds. After the conflagration has been visible for a few months, the stars have disappeared. May the Creator of the universe, grant that we may be prepared for that hour, when our works shall be tried by fire.

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